Tone Signaling at Motorola Incorporated (A)

Dr. John Davis,* Chief Engineer, Communications Division, Motorola Incorporated, organized a technical group in his division in early January 1950 to study problems of improving tone signaling over frequency modulation (FM) communications systems. Dr. Davis indicated he felt the devices would be based upon frequency selectivity and that the solution might require a rather sophisticated tuning fork type metal resonator with very high Q, temperature stability, etc. However, in line with his policy of encouraging original thought in his division, he did not discourage other possibilities such as inductor-capacitor resonators.

* Names of all personnel and of all firms except Motorola are fictitious.

This case was prepared by Professor Luther E. Johnson, The Citadel, during the 1967 Summer Institute on Case Methods supported by the National Science Foundation at the University of Illinois. The able assistance of Dr. Jona Cohn, Mr. Joe Loos, and Mr. James Treatch of Motorola Incorporated, is gratefully acknowledged.

Motorola Incorporated

Motorola's beginning dates from 1928 when Paul and Joe Galvin started a small battery eliminator business in Chicago with a capital of $565.00. As Mr. Bob Galvin, son of Paul Galvin and President of the Board puts it: "Their first engineering breakthrough was an integrated automobile radio, and to this day Motorola has never relinquished its leadership in the automobile radio field." Mr. Galvin says: "Engineering 'firsts' have been a hallmark of the company and have contributed greatly to the company's success, but Motorola's accent on people - that people come first and are the most valuable asset the company has - is the greatest factor."

Today Motorola is one of the largest electronics manufacturers in the world. In 1966 sales were nearly $700,000,000.00 and earnings were nearly $33,000,000.00. Employees number over 33,000 people in six divisions. Each of these divisions is a product division. That is, it researches, develops, and manufactures end products for sale. However, the percentage of research and development (R & D) varies considerably. The Communications Division, the division with which this case is concerned, has a higher percentage of R & D than most of the other divisions. This division has a significant number of technical personnel and 90% are graduate engineers of many disciplines, but the majority are electrical.

The six product divisions are as follows:

The Communications Division Headquarters at Schaumburg Village, on the outskirts of Chicago, Illinois, and plants in Chicago covers all mobile and portable communications products.

The Consumer Products Division at Franklin Park, Illinois, covers a full range of sight and sound consumer products.

The Automotive Products Division at Franklin Park, Illinois, and at Arcade, New York, covers car radios, alternator systems, transistorized ignition systems, stereo tape players, and automotive electronics.

The Government Electronics Division at Chicago, Illinois, and Scottsdale, Arizona, covers such areas as aerospace ground control and checkout, unified space and tracking and guidance systems, etc.

The Semiconductor Products Division at Phoenix, Arizona, covers a broad line of solid state products such as logic and linear integrated circuits, silicon annular transistors, varactors, etc.

The Control Systems Division at Phoenix, Arizona, covers the areas of instrumentation and industrial analog and digital control systems, etc.

Although the Communications Division is not as well known to the general public as the Consumer Television and Automotive Radio Divisions many people in the communications world consider "mobile communications" and "Motorola Two-Way Radio" as synonymous terms. Members of the Communications Division take pride in their communication industry leadership and feel that they are technical leaders in the field.

At the first meeting of Dr. Davis' technical group, he assigned the project for improvement of tone signaling to Mr. Bob Jackson's branch (Appendix A-1 is a brief description of a frequency modulation communications system). It was agreed that the device for use in receivers should:

(a) Have a selectivity band width of 2.5 to 7.5 cps in the frequency range of 100 to 300 cps. The old device had a band width of 10 to 30 cps in the frequency range of 100 to 300 cps; thus, the new device would provide four times more audio codes.

(b) Be relatively insensitive to shock such as that caused by the vehicle crossing railroad tracks or driving across country. The old device was susceptible to shock falsing that would allow noise bursts to be heard.

(c) Have a volume not greater than 2 cubic inches and a weight not greater than 100 grams. The old device required a support mass at least 500 times larger than the resonant cantilever mass.

When Mr. Jackson assigned the project to Al Smith, as the project engineer, he said: "Al, let me see the Project Proposal and Project Planning Chart within a week."

Al Smith is typical of the engineers in the Communications Division. He went to work for Motorola immediately after obtaining his B.S. in electrical engineering six years ago from the University of Illinois. Al has several young engineers working under his general supervision on various projects. Their majors include mechanical, electrical, and industrial engineering and physics. Before assigning specific tasks for the project, Al decided to review material covering Motorola's current version of the device, known as a vibrasponder in receivers and as a vibrasender in transmitters. Al was very familiar with these devices, but just to be sure of a few points he stopped by the Division's Library and picked up a copy of the material which had been filed with the U. S. Patent Office two years ago but had not yet been granted. (It is not at all unusual for two years or more to elapse between the time an application is filed and a patent is granted.) As previously indicated, Appendix A-1 is a brief description of an FM communications system. The last two paragraphs briefly describe the operation of the vibrasponder and vibrasender in the system. Al knew that the principal deficiencies of the devices were their sensitivity to shock, the need to have an overall mass several times as great as the mass of the reed, and the excessive width of the selectivity band width.

Al was pretty sure Motorola's competitors had not yet put a tone signaling device on the market, but just to be sure he said to Dave Jones who happened to be passing his desk: "Dave, has Car Radio, or any of our competitors, come up with anything on tone signaling yet?" Dave said: "I don't know, but I'll check. I'll be going past the Sales Department on my way to the Library. They will know if anything has been put on the market recently - sometimes they amaze me." "O.K. Dave, you check with Sales and I'll touch bases with our Marketing people to make sure we are going in the right direction."[1]

Being an electrical major, Al quite naturally said to himself: "There should be an all electric method which would not require a vibrating reed and certainly not a switch which depends upon mechanical contacts." Al muttered to himself: "Such methods are outmoded in this electronic age." He felt sure he could come up with a more sophisticated method. He decided to determine the band width of the simple frequency responsive circuits shown in Figures 1 and 2. First, he determined the band widths simply in terms of the parameters R, C, and L. He then tried some practical values of the parameters for a frequency of 628 radians per second.

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1 If one of Motorola's competitors had a tone signaling device, Al would have reviewed their product to see what he was competing with and then try to design his product better than theirs. Such practice is quite ethical and failure to do so would be considered poor judgement. Of course, he would take steps to be sure that no patent infringement was involved. This is one place the company's lawyer should be consulted to be sure there is no patent infringement involved.

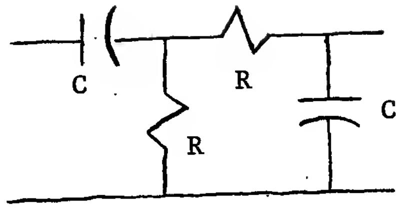

Figure 1. R - C Circuit

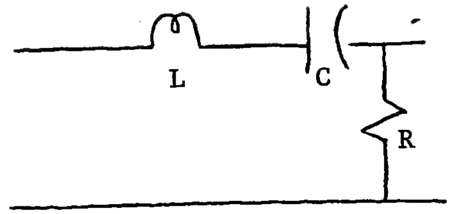

Figure 2. L - C Circuit

After making the preliminary studies, reviewing some fundamentals of circuits and physics, and consulting certain handbooks, Al met with his assistants to brief them on the project, give them a few "gems of wisdom", obtain their ideas, and assign their tasks. Al decided that only he and one other engineer, Dave Jones, would formally work on the project. He felt two people could work on it most efficiently and could meet the deadline. Furthermore, the others had projects a plenty to keep them profitably employed. Nevertheless, Al had his group in for the initial conference, as previously mentioned. He wanted to keep them informed, and, who knows, perhaps one of them might come up with a needed solution during a session over a cup of coffee.

Dave Jones had been with the group since his graduation two years ago from Northwestern. Al knew he had a find in Dave. Dave is one of those meticulous fellows who won't go on until he has made theory and reality agree.

Al met Bob Jackson's deadline on the Project Proposal, Exhibit A-1, and the Project Planning Chart, Exhibit A-2.[2] The Project Proposal, Exhibit A-1, is somewhat more abbreviated than is normal. Some companies require a much more detailed proposal. The burden of overhead is included by many companies in the costs. It is often estimated in engineering divisions by simply multiplying the labor costs by a factor. Two is a typical factor.

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2 The actual dates are the dates by which Al and Dave actually completed the respective phase of the project. They, of course, are not on the chart originally, but are added as the respective phase is completed.

Now, after about eight months of trials and tribulations, as well as triumphs, Al and Dave feel they have met the specifications. Their path has been one that is typical of the progress engineers normally make when solving a difficult problem. If we could plot it on a plane, it probably would be more nearly represented by the solid line in Figure 3, than the dotted line - - straight to the goal as in many textbook solutions.

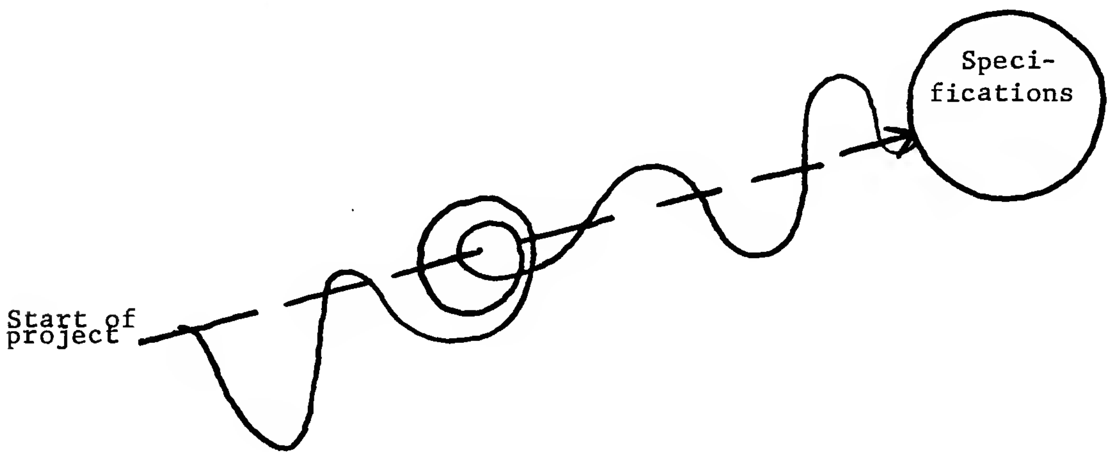


Figure 3.

Note to the student: What are your specifications, to include as a minimum the principle or concept for achieving each of the objectives agreed upon by Dr. Davis and Mr. Jackson? Also, include any additional specifications which will result in worthwhile improvements of the device.

Frequency Modulation Communications

Frequency modulation communications systems are systems in which the frequency of the carrier wave (the unmodulated radio frequency -- R F) is made to vary as nearly as practicable in direct proportion to the amplitude of the modulating signal (the intelligence which is to be conveyed) and in which the rate of variation of the R F is proportional to the frequency of the modulating signal. Thus a plot of an F M wave is as shown in Figure 4.

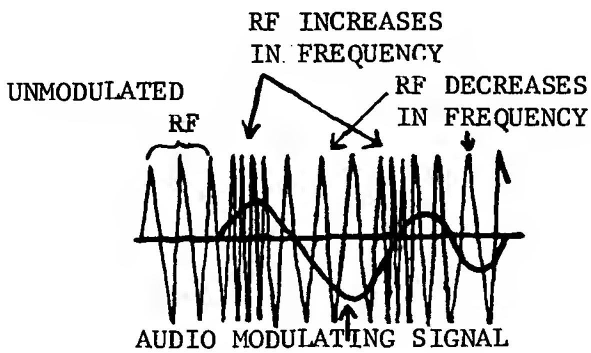


Figure 4.

A frequency analysis of an F M wave shows that it requires a greater bandwidth than does a comparable amplitude modulated (A M) wave. This is a drawback of F M, but due to other advantages, e.g., the fact that an F M system can easily be designed so it is not nearly so susceptible to interference as is A M, has resulted in wide spread use and development of F M systems for communications, particularly in short range vehicular systems. This is possible, since as may be seen from Figure 1, the amplitude of the F M wave is constant when there is no interference, whereas in the presence of interference, the amplitude of the resultant wave (the F M and interference combined) varies. Consequently, interference can be easily eliminated from an F M wave by the simple expedient of including a limiter stage in F M receivers. See Figure 5. A limiter is essentially an amplifier whose output remains constant irrespective of the amplitude variations of the input. A basic F M communications receiver is shown in Figure 6.

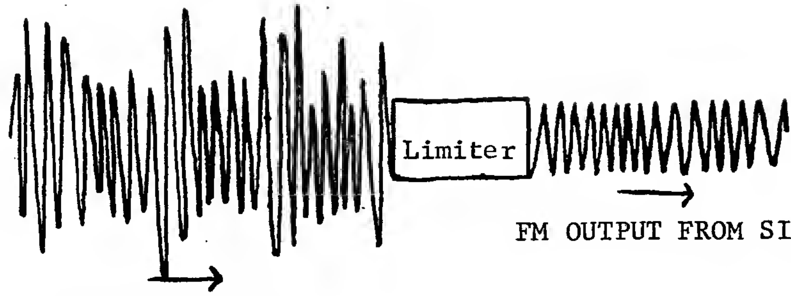


Figure 5. Action of a Limiter

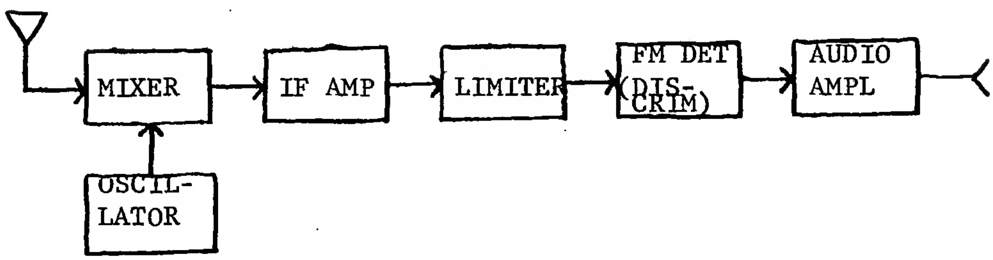


Figure 6. Basic F M Receiver

The F M detector or discriminator, as it is commonly called, recovers the audio intelligence from the incoming frequency deviations by converting these deviations into corresponding deviations in amplitude of the output voltage or current.

In an ordinary commercial F M broadcast receiver, the transmitter carrier is present even though the modulation may be temporarily discontinued. In the case of the communications receiver the situation is different -- the carrier is present only when a message is being transmitted. During the intervals between these messages the carrier is removed. In the absence of any RF to provide this quieting, noises entering the receiver as well as noises generated within the receiver itself cause an objectionable noise or "hiss" in the speaker. This is particularly bothersome when the receiver must be monitored constantly. A squelch circuit quiets the receiver between transmissions by preventing the noise voltages from passing through the audio stages and reaching the speaker. As shown in Figure 7 the squelch system

operates into the first audio amplifier, preventing that stage from functioning. Without an incoming signal (between transmissions), the

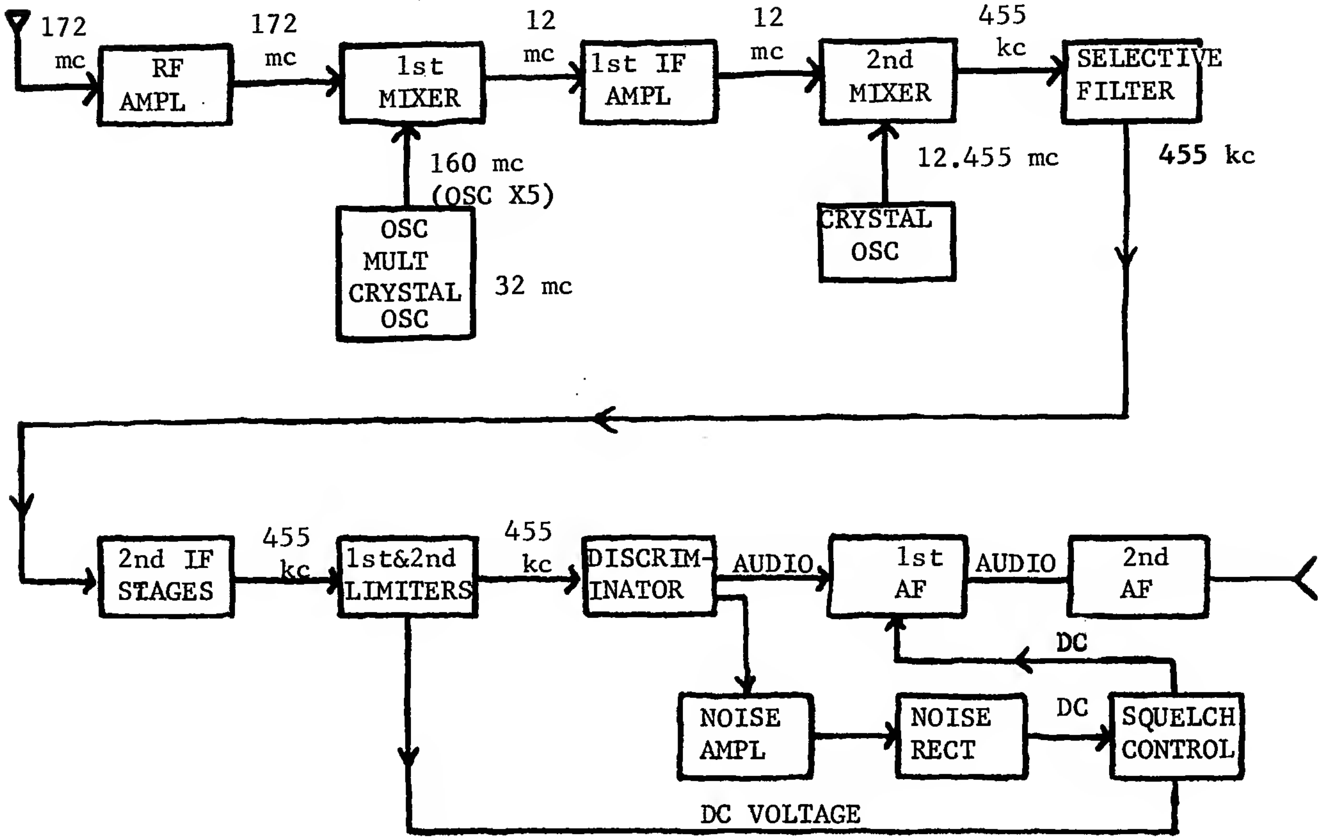


Figure 7. FM Communications Receiver

noise cannot get through the audio stage to the speaker. As soon as a signal is received, however, the squelch circuit becomes inoperative and the audio works normally. Thus the squelch controls the output of the receiver so that there is an output to the speaker only when a signal is being received. At other times when the carrier is removed, although the antenna may be picking up noise and noise may be generated in the receiver, the action of the squelch prevents any output to the speaker.

Due in large part to the very extensive use of FM mobile communication the Federal Communications Commission (FCC) has found it necessary to assign each of the channels in the 144-174 mc band to several customers in many areas. For example, in Chicago twenty

customers share the 160 mc channel. Generally, in such cases, all the receivers within the power range of each transmitter will receive signals from that transmitter. In some applications this may be permissible, or even advantageous, but in many systems it is desirable that only certain receivers reproduce signals from each transmitter to prevent the continual chatter on a busy channel from being an annoyance or even a safety hazard. To prevent such situations, a selective calling provision can be included so that a station will reproduce only signals having possible information for that station.

At the time Dr. Davis organized his technical study group to study problems of improving tone signaling, it was fairly common practice to employ a selective switch having one of its contacts on a reed. The reed would vibrate sufficiently to close the switch only when a certain low audio tone was received.

Thus, if each customer on a channel used a certain tone which his transmitter included in his modulation signal, only the receivers having reeds which responded to this particular tone would "open up" and reproduce the signal. Other receivers on the channel having reeds that responded only to some other tone would not open up. Superposition of a tone (having a frequency in the range from 100 to 300 cps) on the modulating signal of the transmitter has little effect on the fidelity of voice transmissions if it is filtered out before it reaches the speaker. By far, most of the energy of the voice is included in the frequencies between 300 to 3,000 cps. Elimination of all frequencies below 300 cps is hardly noticeable. Figure 8 is a block diagram of a Motorola "Private Line" FM receiver which employs a tone operated reed device, the vibrasponder. The entire front-end, low-frequency IF, limiter, and discriminator sections of the receiver are the same as for any conventional receiver. The point of difference is to be found in the squelch circuitry. The discriminator output contains the audio message which is to be reproduced; it also contains the Private Line tone signal. This output is applied both to the low-pass amplifier and to the audio amplifier. Filters in the low-pass amplifier reject the higher audio signals, passing only those frequencies below 300 cps.

The coding tone thus reaches the limiting amplifier where it is further amplified. The amplification is sufficient to properly drive the resonant reed.

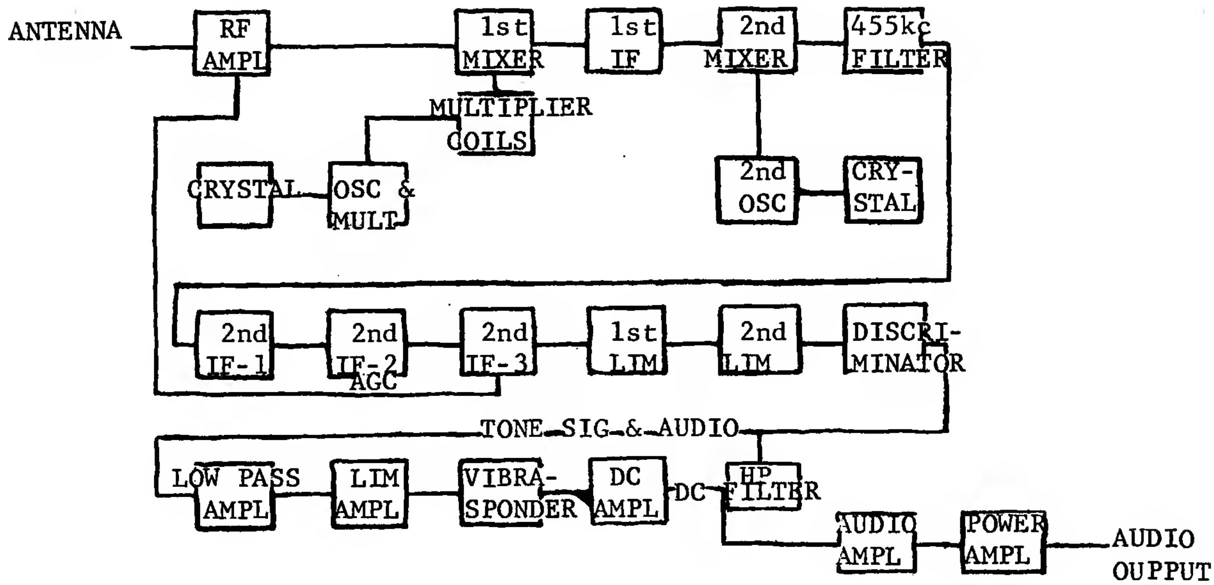


Figure 8. Motorola "Private Line" FM Receiver

When the correct tone is received, the reed is energized, closing the contacts so as to apply a negative DC bias voltage to the grid of the DC amplifier stage. This negative voltage disables the squelch, allowing the receiver audio section to operate normally. When the correct tone is not present to operate the vibrasponder, the negative voltage does not reach the DC amplifier, the squelch is closed, and the receiver is silent. Thus, the only time that the receiver audio section is operative is when a tone of the proper frequency is received. A high pass filter is used to prevent the signal tone from reaching the speaker.

The highest frequency used for the audio tone is considerably lower than the audio voice range used in two-way communications (300-3000 cps). It is therefore improbable that any normal voice transmission will open the squelch.

Motorola Engineering Project Proposal*

Improved Tone Signaling Project Engineer: Al Smith

I. Purpose:

The purpose of this project is to develop a smaller, lighter, better performing electro-mechanical reed for Motorola selective signaling systems.

II. Engineering Proposal:

The engineering development areas to be explored are:

1. High Q components will be incorporated so that better selectivity can be obtained and 2.5% channel spacings will be practical.
2. Spring suspension will be investigated to provide:
   a. External shock and vibration isolation.
   b. Size and weight reduction.
   c. Higher frequency operation.
3. Raise electrical impedance to 600 ohms for better electrical circuit power matching.

III. Development Schedule:

	Large scale breadboard model	Actual size working model
Starting Date:	1/7/50	5/12/50
Finish Date:	5/10/50	8/1/50

IV. Costs:**

Sources of Expenditure	Manweeks	Dollars
Engineering	70	$10,500
Model Shop	4	300
Drafting	4	300
Materials		400
Total		$11,500

* Several of the entries have been abbreviated considerably to prevent revealing concepts at this time.
** Remember this was early 1950. Also these costs do not include burden or overhead.

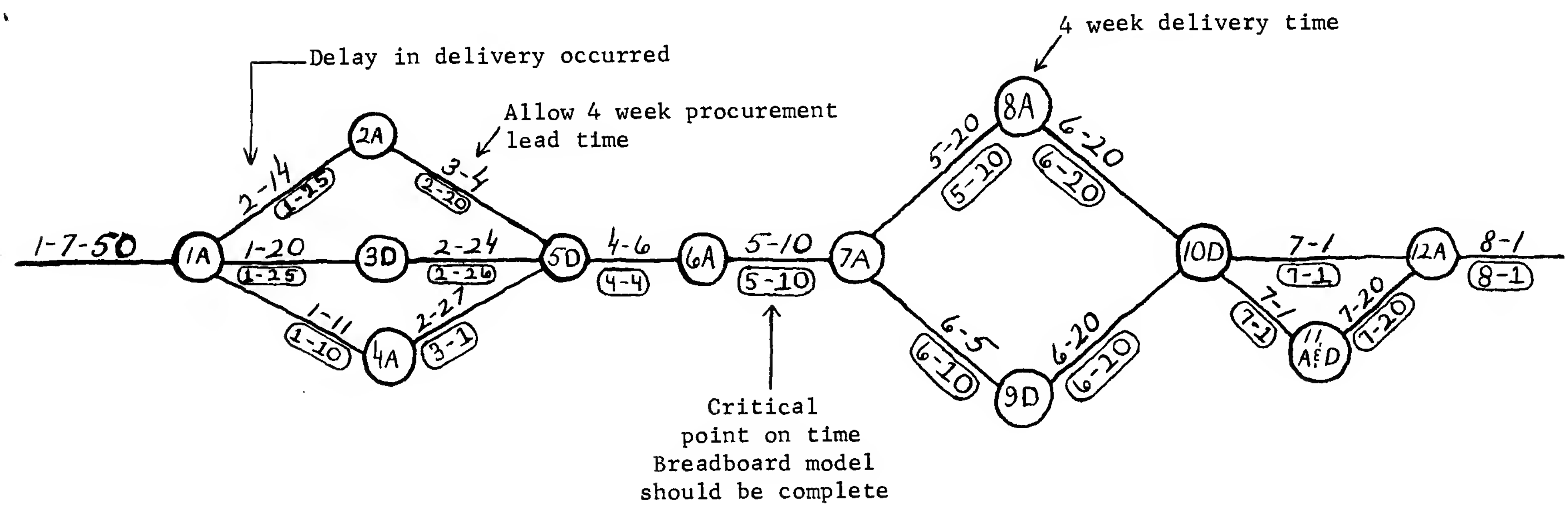
V. Approvals:

____________________ Date: ____________
Al Smith

____________________ Date: ____________
Bob Jackson

____________________ Date: ____________
Dr. John Davis

Progress Planning Chart



KEY: Actual date

Estimated date

A: Al Smith responsible
D: Dave Jones responsible
1, 2, etc: See table at right

Project #12-42-195

1. Buy materials
2. Component tests
3. Circuit design
4. Suspension system design
5. Lab assembly of breadboard model
6. Test and evaluate lab model - mechanical and electrical
7. Start design and layout of actual size device
8. Procure parts
9. Start model shop fabrication of actual housings
10. Assemble actual size model and test
11. Resolve final problem areas
12. Make final analysis, finalize prints and prepare process for production

ENGINEERING CASE LIBRARY

ECL 99B

Tone Signaling
at
Motorola Incorporated (B)

A patent, issued by the United States Patent Office, based primarily on Al's specifications, was issued on August 31, 1954. See Exhibit B-1.

It is now January 4, 1956. Al's resonant reed device resulted in definite improvement over the original device. It is now in widespread use. However, it has been found that resonant reed devices tend to continue vibrating for a short period after a transmission has ceased. Since vibration of the reed device in the receiver maintains the squelch circuit open, even after the carrier has been cut off, and since the receiver produces noise under these circumstances (when the squelch is open and no carrier is received) a short blast of high level background noise is emitted from the receiver at the termination of each transmission. This "squelch tail" may be of the order of 1/3 of a second. The effect is annoying to an operator during use and reduces the usable time of the system.

This case was prepared by Professor Luther E. Johnson, The Citadel, during the 1967 Summer Institute on Case Methods supported by the National Science Foundation at the University of Illinois. The able assistance of Dr. Jona Cohn, Mr. Joe Loos, and Mr. James Treatch of Motorola Incorporated, is gratefully acknowledged.

At a technical group meeting today, Dr. Davis said: "There are at least three improvements which are definite objectives of this project. First, to provide a two-way selective calling communications system which operates more quietly at the termination of each transmission; and second, which permits faster communication among stations of the system by reducing the time required for the reed or other device to cease vibrating." Continuing he said: "The third is to eliminate the need for manual sensitivity adjustment of the squelch and to provide a less critical tone modulation level at the transmitter."

Suggested Assignment:

You are Dave Jones, the project engineer assigned the research and development required to effect the three improvements Dr. Davis has called for. (Al moved up sometime back and Dave is in charge. He has several assistants; his responsibilities are similar to those Al had.)

Aug. 31, 1954 A. S. HOLZINGER ET AL 2,688,059

ELECTROMECHANICAL DEVICE

Filed Aug. 14, 1950

Fig. 1.

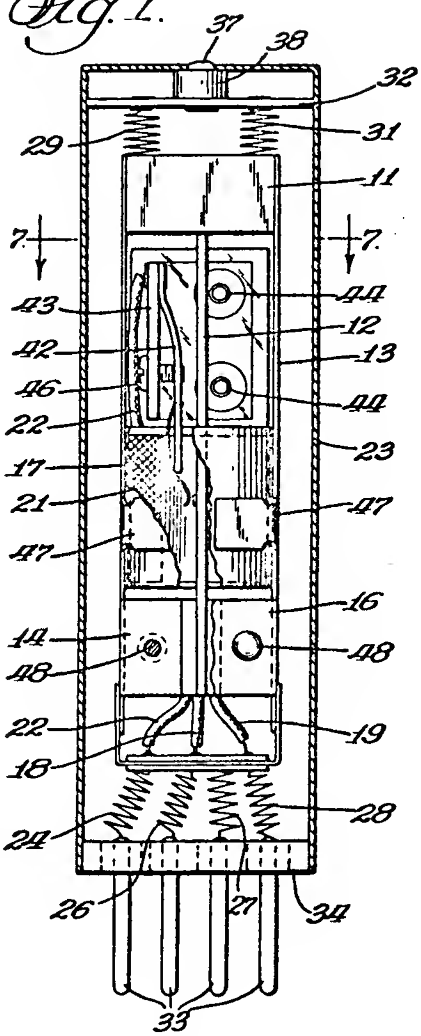
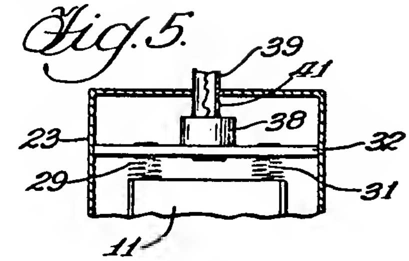


Fig. 5.



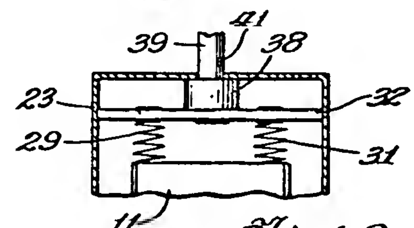
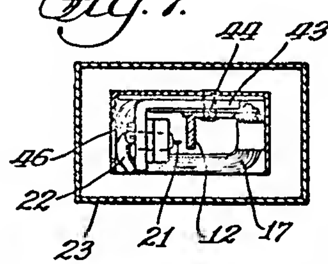


Fig. 6.

Fig. 7.



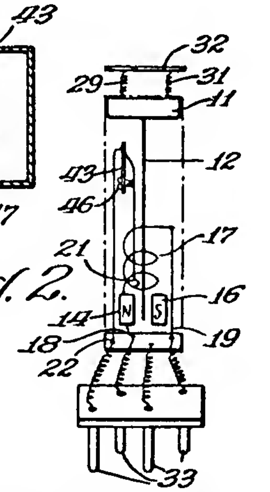
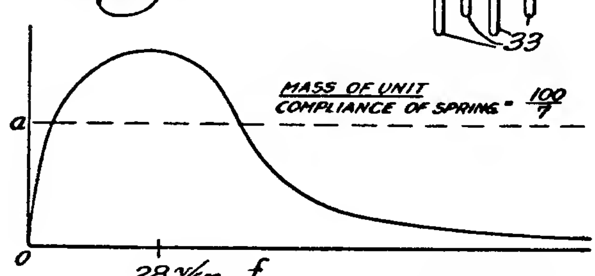


Fig. 2.

Fig. 4.



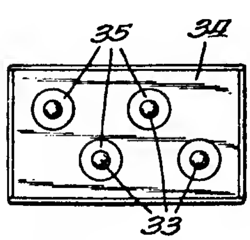


Fig. 3.

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Patented Aug. 31, 1954 2,688,059

UNITED STATES PATENT OFFICE

2,688,059

ELECTROMECHANICAL DEVICE

Alfred S. Holzinger and Robert Peth, Chicago, Ill., assignors to Motorola, Inc., Chicago, Ill., a corporation of Illinois

Application August 14, 1950, Serial No. 179,114

5 Claims. (Cl. 200—91)

1

This invention relates generally to selective electro-mechanical switching or contacting devices. More particularly, the invention relates to a frequency selective electric switch of the type having as one of the contacts thereof a vibrating reed which is adapted to distinguish between electrical signals having closely adjacent frequencies.

The use of systems for remote signalling and remote control are now well known and are continually finding new applications. The need for simple and dependable structures and systems which are highly selective has become more acute. As an example, in two-way communication systems, and particularly in a two-way mobile communication system, it is necessary to provide some means for advising one station that another station desires to communicate with it. For operational reasons, it is essential that such means utilize the normal communication channel and be completely automatic, in that it utilizes the received calling signal to actuate a light or other indicating device, or to condition a receiver for operation when its particular calling signal is received. In the past such selective systems have utilized electrically operable selective switching or contacting mechanisms having a vibrating reed as one of its contacts. It is well known that if a reed is physically distorted and released, it will mechanically vibrate at a natural frequency determined mainly by its physical dimensions. By providing selective switches in each of the stations with vibrating reeds having natural or resonant frequencies, different than the resonant frequencies of the reeds of other stations, such a calling system can be provided. In order that the system operate satisfactorily, however, each of the vibrating reed structures must be sufficiently selective so that it responds only to a desired calling signal having a frequency substantially equal to the resonant frequency of the reed, but is substantially unresponsive to other calling signals having frequencies relatively closely adjacent its resonant frequency. This characteristic is referred to as the selectivity of the reed.

There are two important factors which determine the ultimate selectivity of vibrating reed contact making devices. The first factor is the resonant frequency of the reed, or the frequency at which the reed will vibrate at its maximum amplitude for a given driving force, and the second is the sensitivity or the amount driving force necessary to cause the contacts to open and close when the driving force is at the resonant frequency.

2

The resonant frequency of a vibrating reed is determined by several factors, all of which must be considered when designing a switch to respond to a particular calling frequency. In known selective switches of this type these factors have been satisfactorily accounted for, with the exception that difficulty has been encountered in providing a mounting for the working mechanism, or reed structure itself, which prevents transfer of vibrations through the mounting to the reed structure. By providing a very heavy and solid mounting, this difficulty has been overcome to some extent, but such a mounting results in outside loading effects, is not completely effective in shielding the reed from outside vibrations, and further adversely affect the selectivity of the switch. Additionally, the range of frequencies covered by switches having reeds mounted in this fashion, is limited because of manufacturing complications arising in the higher frequency units.

It is therefore one object of the present invention to provide a small, compact and inexpensive selective switch mechanism for use in mobile communication equipment, having a vibrating reed contact for providing frequency selective operation.

Another object of this invention is to provide an electrically operable, vibrating reed selective switch mechanism for use in mobile communication equipment, and having improved frequency selectivity characteristics.

A further object of the invention is to provide a vibrating reed switch mechanism having a novel means for mounting the vibrating reed structure on a supporting chassis which is effective to prevent the transfer of reed vibrations to bodies other than the reed structure, and to prevent the transfer of disturbances having frequencies in the vicinity of the calling frequency, to the reed.

A feature of the invention is the provision of a vibrating reed structure having resilient spring mounting means for supporting the reed structure from a supporting chassis.

Another feature of the invention is the provision of a spring mounted, mechanical vibrating reed structure contained within a housing having an orifice therein, the spring mounting means for the reed being utilized to close a valve mechanism over the orifice in the housing.

Other objects, features, and many of the attendant advantages of this invention will become apparent from a consideration of the following description taken in connection with the accompanying drawings, wherein:

Fig. 1 is a longitudinal sectional view of a novel selective electric switch constructed in accordance with the invention;

Fig. 2 is a schematic diagram showing the functional elements of the mechanism illustrated in Fig. 1;

Fig. 3 is a bottom view of the switch mechanism;

Fig. 4 is a graph illustrating the amplitude of vibration versus the frequency characteristic of a portion of the switch mechanism shown in Fig. 1;

Fig. 5 is a fragmentary sectional view of a novel valve structure made possible by the invention, and showing the valve structure in the first of its operative positions;

Fig. 6 is a fragmentary sectional view of the valve structure showing the same in a second of its operative positions; and

Fig. 7 is a cross sectional view of the novel switch mechanism taken through plane 7—7 of Fig. 1.

In practicing the invention, a selective electric switch mechanism is provided including an outer housing supporting an inner housing therein. A reed member constructed of magnetizable material, and supported at one end, is secured within the inner housing along with a permanent magnet having its poles positioned on either side of the free end of the reed member. An electrically operable coil is positioned adjacent the magnet and surrounding the reed member. A flexible contact having a mounting for suppressing vibrations thereof is positioned to be engaged by the reed and the reed and contact are connected in an electrical circuit. The dimensions of the reed are selected so that a predetermined natural frequency of vibration is provided, and when an electrical signal is applied to the coil, having a frequency substantially equal to the frequency of vibration of the reed, the reed vibrates to close the electrical circuit through the switch contact. To prevent transfer of vibrations from the inner housing to the second or outer housing, the former and all of its component parts are supported within the outer housing by resilient spring means, and the mass of the inner housing taken in connection with the spring means has a frequency of vibration which is substantially lower than the lowest frequency used in the system in which the vibrating reed switch structure would be applied. The mounting therefore tends to prevent application of frequencies within the reed range from being applied from an external source, to the reed structure and to prevent the loading effect of external bodies on the reed vibrations. The resilient spring means are also utilized as lead in electrical connections for the mechanism and for providing a valve for closing an opening in the outer housing.

Referring now to Fig. 1 of the drawings, the switching mechanism includes a base member 11, and a lever member or vibrating reed 12 constructed of a magnetizable material. The vibrating reed 12 is rigidly secured to the base 11, and, generally speaking has considerably less mass than the pedestal. The reed 12 and base member 11 are positioned in a first, or inner sheet metal housing 13 of rectangular construction, with the vibrating reed 12 extending along the longitudinal axis of the housing. Housing 13 also contains a permanent magnet means having one pole 14 positioned on one side of the free end of reed 12, and the other pole 16 positioned on the opposite side of reed 12. Physically disposed adjacent permanent magnet 14—16, and surrounding reed 12, is a coil winding 17 which may be connected by a pair of lead-in conductors 18 and 19 to a source of calling signals derived from a radio receiver, or the like. Housing 13 also contains an electric switch contact assembly including a fine wire contact 21 connected to a lead-out electrical conductor 22, and physically disposed adjacent one side of reed 12 so as to be engaged by the reed upon the same being pulled towards it. Upon connecting the reed 12 to one side of an electrical circuit to be controlled, and the conductor 22 to the remaining side of the same circuit, the mechanism heretofore described will operate as a selective switch for controlling the application of electric energy thereto. Referring next to Fig. 2, the components of the selective switch described in Fig. 1, are illustrated schematically. When an alternating electric signal is applied through conductors 19 and 18 to coil 17, a varying magnetic field is produced around the coil in accordance with the principles of electromagnetism. This field either adds to, or subtracts from the field produced by permanent magnets 14 and 16, depending upon which half cycle, the signal applied to coil 17 is passing through. As previously stated, reed 12 is constructed of a magnetizable material, and is normally positioned midway between poles 14 and 16. During one half cycle of the applied signal, the combined field of magnets 14 and 16, and coil 17, causes the end of reed 12 to be pulled to one side, and upon the applied signal passing through the next succeeding half cycle, opposition of the two fields allows the reed to flex back toward its normal position. It is apparent, that if the signal applied to coil 17 is of the same frequency as the resonant frequency of vibration of reed 12, the varying magnetic field thus produced, will cause reed 12 to vibrate at its resonant frequency. This is due to the fact that the natural flexure of the reed 12 will be in phase with, and augment the motion produced therein by the varying magnetic field. Reed 12 thereby vibrates at a maximum amplitude, and serves to close the electrical circuit through contact 21 during a portion of each vibration period; thereby controlling the application and energization of the electrical circuit in which the switch formed by contact 21 and reed 12 is included.

As previously stated, for proper operation of a unit as described above, it is necessary to prevent outside loading of the reed, as well as the mechanical application of disturbances thereto which are of frequencies closely adjacent to that of the reed, and might therefore cause vibration of the reed. In structures which are directly connected to a chassis or other support the effect of vibration transfer may be reduced by making the mass tof the entire structure much greater than the mass of the reed. However, as the reed frequency goes up, the mass thereof increases and the ratio of the mass of the mounting to the mass of the reed tends to decrease. To overcome this, attempts have been made to secure the contactor structure rigidly to a large body such as a supporting chassis but it is apparent that the effective mass of the unit in such case depends upon the rigidity of the securing means. These problems are overcome in the system which provides a resilient mounting for the switch structure which is resonant at a frequency much lower than the frequencies selected and bypasses higher frequencies to thereby isolate the reeds

from external vibrations of the frequencies to which the reeds respond.

Adverting again to Fig. 1, the first or inner housing 13 is contained within an outer housing 23 of copper or the like, and is freely supported therein by resilient spring means. The resilient spring means includes a first group of electrically conductive, resilient springs 24, 26, 27 and 28, physically connected between inner housing 13 and outer housing 23, and a second group of resilient springs 29 and 31 physically connected to inner housing 13, and to an insulating plate 32 secured to outer housing 23 in a manner to be described hereinafter. Springs 24, 26, 27 and 28, are electrically connected to conductors 22 and 18, inner housing 13, and conductor 19 respectively, and serve to energize contact 21, reed 12 and coil 17, as well as to provide physical support for inner housing 13. The remaining ends of springs 24, 26, 27 and 28 are connected to a plurality of prongs 33 which, as is best shown in Fig. 3, are mounted in the base 34 of outer housing 23, by means of a plurality of insulating bushings 35 secured to base 34. The end of housing 23 opposite base 34 has an orifice 37 centrally disposed therein for a purpose, hereinafter to be explained. Orifice 37 is closed by a cylindrical disc 38 centrally mounted on plate 32, and biased into a position to close orifice 37 by means of springs 29 and 31. In a completed structure, the metallic disc 38 is soldered to the top of outer housing 23, and permanently closes orifice 37. By this construction, a compact self-contained selective switch is provided, which may be easily installed on a supporting chassis of the equipment with which it is to be used.

By properly proportioning the mass of inner housing 13 including base 11, reed 12, permanent magnet means 14 and 16, coil 17, adjustable contact 21, and conductors 18, 19 and 22 to the compliance of springs 24, 26, 27, 28, 29 and 31, the reed 12 can be effectively isolated from external loading, thereby greatly improving its selectivity. The ratio of the mass of housing 13 and all its components to the compliance of the spring, hereafter called the ratio of mass over compliance, is relatively critical, as this ratio controls the resonant frequency of the housing 13 plus all its components and the springs, hereinafter called the unit, for satisfactory operation, it must be such that resonant frequency of the unit is lower than the lowest calling frequency used to actuate the switch. It has been determined that structures in accordance with the invention can be constructed with the ratio of the mass of the unit to the compliance of the springs of approximately 100:7, and the resonant frequency of the unit will then be around 28 cycles. This is substantially below the range of frequencies which will normally be used in a calling system as they start at about 100 cycles.

Referring now to Fig. 4 of the drawings wherein the frequency of vibration of the unit is plotted along the y axis and the amplitude of oscillation or vibration is plotted along the x axis, the response of the unit to varying vibration frequencies is shown. It can be seen that the maximum amplitude of vibration occurs at approximately 28 cycles, and thereafter drops considerably below the amplitude of vibration of the reeds, as indicated by the dotted line. The amplitude of vibration is substantially constant at a very low order amplitude throughout the remaining portion of the frequency spectrum. From this graph it can be seen that above approximately 60 cycles, the effect of vibration of the mass of the unit on the vibration of any one of the reeds, is negligible, and is substantially constant for all higher frequencies, thereby effectively isolating the response of any one of the reeds from the response of the mass of the unit, and rendering all of the frequencies above 60 cycles available for use as calling frequencies.

As a further feature, the invention renders possible a novel means for dehumidifying the inside of the outer housing 23. In mechanically operating devices, it is essential that the device be mounted in a substantially moistureproof container to prevent spoilage from rusting, and the like. The moisture-proofing of such devices can be a relatively expensive operation. Because of the valve means provided by the construction of insulating plate 32, cylindrical disc 38, springs 29 and 31, and orifice 37, the dehumidification of the interior of outer housing 23 is easily accomplished. Referring now to Fig. 5, when the selective switch mechanism shown in Fig. 1 is assembled, a tube 39 is inserted in the orifice 37 of the outer housing 23, and cylindrical disc 38 depressed away from the housing. The tube 39 has an orifice 41 in one side of the end thereof, and may be connected to a source of nitrogen or the like. By this means the interior of housing 23 can be filled with nitrogen, which is moisture absorbing and which removes the moisture when it escapes. Upon retracting tube 39 from orifice 37, disc 38 automatically closes the orifice, in the manner shown in Fig. 6, thereby sealing the interior of the housing. Disc 38 may then be soldered to outer housing 23, and the housing permanently sealed against the entrance of moisture and air.

In order that the selective switch function properly over a sustained period, electric switch contact 21 is mounted on an adjustable arm 42 secured to an L-shaped member 43, fixed to inner housing 13 by rivets 44 in the fashion shown in Fig. 7. Adjustable arm 42 is secured to plate 43 in a cantilever fashion and is adjustable by means of a set screw 46 to position the contact 21 to be engaged by vibrating reed 12 upon the same being vibrated. Contact 21 comprises a very fine Phosphor-bronze wire secured to adjustable arm 42 at a point in from the end thereof, and bent in such a manner that it bears against the end of adjustable arm 42. By this structure the end of the adjustable arm 42 damps the contact 21 and prevents vibration thereof after it is disengaged by the reed 12. As a further precaution, coil 17 is rigidly secured in place by a pair of bent over ears 47, and permanent magnets 14 and 16 secured in place by rivets 48. Reed 12 is cast integral with its mounting pedestal 11, or, if desired, may be positioned in a well in the pedestal and soldered or welded thereto. The pedestal 11 is of course rigidly secured to inner housing 13 by soldering or the like.

From the foregoing disclosure, it can be appreciated that the invention provides a switch mechanism having a highly selective frequency response characteristic. By reason of the novel manner of mounting the mechanism, the selectivity of the switch mechanism is relatively unaffected by the support on which it is mounted. Further, the novel mounting means for the mechanism provides a unit in which the frequency spectrum for use in selective switch devices may be extended, and proper operation of the switch will be provided in such extended portions of the spectrum. Additionally, the inven-

tion makes possible a novel method of dehumidifying the entire interior of the switch mechanism container, thereby resulting in lower manufacturing costs.

Obviously, other modifications and variations of the invention will be suggested to those skilled in the art by the above teachings. It is therefore to be understood that such changes are within the intended scope of the invention as defined by the appended claims.

I claim:

1. A frequency responsive vibrating device for selectively responding to a predetermined signalling frequency including in combination, a first completely enclosed housing having an orifice therein through which a dehumidifying gas may be passed and which may thereafter be sealed; a second housing contained within said first housing and including a vibratory member constructed of magnetizable material, a permanent magnet having its poles positioned on either side of the free end of said vibratory member, and a coil winding disposed adjacent said permanent magnet and surrounding said vibratory member; a first group of resilient springs secured to both of said housings; a second group of resilient springs secured to said second housing and to a movable plate within said first housing, and valve means secured to said plate and cooperating with the aforesaid orifice to close the same, said resilient springs of said first and second groups freely supporting said second housing within said first housing, and the resonant frequency of vibration of said vibratory member being greater than the resonant frequency of vibration of said second housing and said resilient springs.

2. A selective frequency responsive switch including a first completely enclosed housing having an orifice therein through which a dehumidifying gas may be passed and which may thereafter be sealed and further having a plurality of electrically conductive prongs secured thereto, a second housing contained within said first housing and including a lever member constructed of magnetizable material, a permanent magnet having its poles positioned on either side of the free end of said lever member, a coil winding disposed adjacent said permanent magnets and surrounding said lever member, and an adjustable electric contact adapted to engage said lever member, said selective switch further including electrically conductive resilient spring means secured to both of said housings for freely supporting said second housing within said first housing and for supplying electrical energy to said coil and the switch formed by said lever member and said adjustable contact, said spring means also being electrically connected to said prongs, and valve means fixed to said spring means and cooperating with said orifice for closing the same, the resonant frequency of vibration of said lever member being greater than the resonant frequency of vibration of said second housing and said spring means.

3. A frequency responsive switch adapted to respond to a predetermined signalling frequency above 60 cycles per second including in combination, a switch structure including a housing having a vibratory member made of magnetizable material supported therein, said vibratory member being mechanically resonant at a predetermined frequency above 60 cycles per second, electrically operable means within said housing for producing a fluctuating magnetic field about said vibratory member in response to the application of signaling frequencies thereto, with a field fluctuating at said predetermined frequency causing vibration of said member, said switch structure including a resilient contact positioned to be engaged by said vibratory member when the same is operated and forming therewith the contacts of an electric switch, a supporting chassis for said switch structure, and resilient mounting means including a plurality of coil springs for supporting said housing on said supporting chassis, said springs providing electrical connection to said electrically operable means and said switch contacts, the ratio of mass over compliance of said switch structure and said resilient mounting means being such that the resonant frequency of vibration of said switch structure and resilient mounting means as a unit is approximately 28 cycles per second.

4. A frequency responsive vibrating device for selectively responding to signals of a predetermined frequency above 60 cycles per second including in combination, frame means, a vibratory member of magnetizable material mechanically resonant at said predetermined signalling frequency above 60 cycles per second mounted on said frame means, electrically operable means mounted on said frame means for producing a magnetic field about said vibratory member fluctuating at a rate determined by the signals applied thereto, whereby said vibratory member is caused to vibrate by a field fluctuating at said predetermined frequency, a supporting chassis, and resilient coil spring means for supporting said frame means on said supporting chassis, said frame means and the parts mounted thereon and said supporting spring means forming a resonant vibrating system, said resonant vibrating system having a predetermined mass and a predetermined compliance such that the ratio of said mass to said compliance imparts a natural frequency of vibration to said vibrating system which is less than one-half said predetermined resonant frequency of said vibratory member and reduces to a minimum external loading effects on said vibratory member at said predetermined frequency.

5. A frequency responsive vibrating device for selectively responding to signals of a predetermined frequency above 60 cycles per second including in combination, frame means, a vibratory member of magnetizable material mechanically resonant at said predetermined signalling freabove 60 cycles per second mounted on said frame means, electrically operable means mounted on said frame means for producing a magnetic field about said vibratory member fluctuating at a rate determined by the signals applied thereto, said field causing vibration of said member in response to fluctuation thereof at said predetermined frequency by a signal of said predetermined frequency, a supporting chassis, and resilient spring means for mounting said frame means on said supporting chassis, said frame means together with the parts mounted thereon and said resilient spring means forming a vibrating system, said vibrating system having a predetermined mass and a predetermined compliance such that the ratio of said mass to said compliance imparts a natural frequency of vibration to said vibrating system which is less than one-half said predetermined resonant frequency of said vibratory member and substantially eliminates external loading effects on said vibratory member at said predetermined frequency.

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ENGINEERING CASE LIBRARY

ECL 99C

Tone Signaling
at
Motorola Incorporated (C)

Motorola's solutions to the three problems mentioned in Part B as well as a few other improvements are contained in the patents attached as Exhibits C-1 and C-2; Exhibit C-1 Patent 2,974,221 SQUELCH CIRCUIT and Exhibit C-2 Patent 2,918,571 COMMUNICATION SYSTEM.

This case was prepared by Professor Luther E. Johnson, The Citadel, during the 1967 Summer Institute on Case Methods supported by the National Science Foundation at the University of Illinois. The able assistance of Dr. Jona Cohn, Mr. Joe Loos, and Mr. James Treatch of Motorola Incorporated, is gratefully acknowledged.

United States Patent Office

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2,974,221

SQUELCH CIRCUIT

Robert Peth, Chicago, Ill., assignor to Motorola, Inc., Chicago, Ill., a corporation of Illinois

Filed Jan. 14, 1957, Ser. No. 634,087

5 Claims. (Cl. 250—6)

This invention relates to two-way communication systems and more particularly to squelch circuits for such systems which utilize a code tone for selective calling of stations in the system.

In my copending application Serial No. 555,364, filed December 27, 1955, now abandoned, there is described and claimed a communication system in which stations may be selectively called by signals from a given transmitter which transmits a tone of particular frequency as continuous modulation of the carrier. The receivers which are to be called by such a transmitter include a squelch circuit which is opened to render the receiver responsive only so long as the tone is received. In a tone operated squelch system it is highly advantageous to use carefully controlled tone signals of given frequency such as may be provided by resonant reed devices. Thus, the transmitted carrier can be modulated by a tone outside of the usual modulation range which is closely regulated by a vibratory reed. The receiver squelch would then open when the demodulated signal received thereby actuates a vibratory reed which is resonant at the frequency of this tone. Such a system, generally employing angular modulation equipment (as used herein angular modulation indicates both frequency and phase modulation), can provide a high degree of reliability and security in a system which uses numerous tone frequencies so that many selective calling combinations are possible.

It has been found, however, that resonant reed devices in the receivers may tend to continue vibrating for a short period after a transmission has ceased. Since vibration of the reed device maintains the squelch circuit open and an angular modulation receiver produces noise when no carrier is translated, a short blast of high level background noise is emitted from the receiver at the termination of each transmission. This "squelch tail" may be of the order of 1/3 of a second and could prove to be annoying to an operator during use of the equipment.

Accordingly, it is an object of the present invention to provide a two-way communication system wherein a reduced amount of noise is produced by the receivers at the ends of the transmissions received thereby.

Another object is to provide an improved and fast acting selective calling system for two-way communication equipment.

Still another object is to provide tone coded squelch apparatus for multi-station two-way radio apparatus using resonant reed devices to respond to the code tone and which squelch apparatus is constructed to reduce the inertia effects of the reed devices at the ends of each transmission.

A feature of the invention is the provision of a selective calling communication system in which a tone coded carrier signal is used to hold open the squelch circuit in selected receivers and wherein cut-off of the carrier signal is delayed at the end of each transmission to provide a carrier signal for quieting the receivers during the time necessary for the squelch circuit to close and silence the audio frequency system of the receiver.

Another feature is the provision of a selective calling frequency modulation communication system which uses a tone coded carrier to hold open the squelch circuit of a called station receiver, with the receivers of the system employing resonant reed devices responsive to the code tone, and the transmitter automatically sending a tone modulated carrier of the proper phase to damp the reed devices in the receivers to close the squelch circuit quickly and silently as the transmission ceases.

Further objects, features and the attending advantages of the invention will be apparent upon consideration of the following description and drawings in which:

Fig. 1 is a block diagram of a communication system showing four two-way stations;

Fig. 2 is a diagram of one two-way station showing its transmitter in some detail;

Fig. 3 is a diagram of a station showing its receiver in some detail;

Fig. 4 is a diagram showing a modified form of the transmitter of Fig. 2; and

Fig. 5 is a diagram useful in explaining the circuit of Fig. 4.

In practicing the invention there is provided a two-way communication system wherein selective calling of certain stations is obtained by transmission of a carrier which is continuously modulated by a code tone, which tone is outside the frequency range of the modulation used to relay other information in the system. The receivers have tone responsive squelch circuits using resonant reed devices which are operated by the code tone to open their respective squelch circuits. As the transmission ceases, the usual tone modulation is discontinued immediately, but cessation of the carrier signal is delayed for a fraction of a second so that the carrier signal will continue for the duration of vibration of the receiver reed devices, thereby reducing background noise which might be heard if the squelch circuit were open and no carrier signal were being received. To promote rapid damping of the receiver reed devices, the same code tone, but of different phase, may be applied to modulate the delayed carrier so that this tone damps the receiver resonant reeds and closes the squelch circuits more quickly.

Fig. 1 shows two-way communication stations 10, 12, 14 and 16 which all operate on the same carrier frequency. Each station includes relay means 18, 19, 20 and 21, respectively, which operatively couple either the station receiver or transmitter to an associated antenna. The invention will be described in connection with receiver 23 and transmitter 25 of station 10, and receiver 27 and transmitter 29 of station 12, although it will be obvious that more than one receiver may be selectively called by transmitter 25, and that by using code tones of other frequencies many different selective calling combinations may be provided.

Considering generally the operation of station 10 as shown in Fig. 2, it may be noted that closing of push-to-talk switch 40 on microphone 42 will ground one side of relay 44, the other side of which is coupled through resistor 45 and relay 47 to a positive potential. Thus, relay 44 and 47 will be energized and contacts 49 of relay 47 will be closed to complete a circuit for relay 18, in the energized condition of which power supply 52 is connected to the B-plus circuits of the transmitter and the antenna is connected to power amplifier 54. Signals are applied to power amplifier 54 from the oscillator 56 and through modulator 57 and frequency multiplier 58. Multiplier 58 raises the frequency of the signal from oscillator 55 to provide a carrier signal of desired frequency

which may be of the order of 160 megacycles. Modulator 57 provides angular modulation of the signal from oscillator 56 according to audio signals applied thereto from microphone 42 through the audio system 60 and from the tone generator. Audio signals are applied to the grid of modulator tube 63 in modulator 57 through portions of a resistor network including resistors 64, 65 and 66 which are connected between the control grid and ground.

When the push-to-talk switch 40 is operated and relay 44 is energized, contacts 70 thereof open and remove ground from the junction of resistors 65 and 66 so that a tone from oscillator 72 is applied to the control grid of modulator tubes 63 through resistors 64 and 65. The tone signal from the oscillator or tone generator 72 may be of the order of 100–200 cycles per second which is outside of the frequency range of the modulating signals usually translated in a two-way communication system. A vibratory resonant reed device 75 is used in oscillator 72 for accurate control of the code tone. Since this device is of very high Q and cannot be readily keyed without a starting delay, circuit 72 is operative at all times and contacts 70, when opened, permit application of the tone to the modulator 57. As the reed of device 75 vibrates, the coil thereof acts like a tuned circuit and supplies a signal to the grid of tube 77. This signal is amplified thereby and applied to the grid of tube 78 through capacitor 79. The signal is further amplified in tube 78 and applied through resistor 81 to the grid of tube 77, thereby providing feedback to sustain oscillation. The signal at the grid of tube 78 is made large enough to draw a grid current thus developing a negative bias across resistor 83. This bias acts as a gain control signal for tube 77 to stabilize the oscillator and reduce distortion. The output signal is derived from the anode of tube 78 and is passed through a harmonic filter network 85 to be applied to the grid of modulator tube 63.

Accordingly, it may be seen that when the push-to-talk switch 40 is operated the transmitter will provide a carrier wave which is continuously modulated with a tone from generator 72 and which may be further modulated with audio signals from the microphone 42.

Fig. 3 shows station 12 in greater detail and it may be noted that in the unenergized condition of relay 19, transmitter 29 is not operative but that the contacts of this relay couple radio frequency amplifier 90 to the antenna and apply B+ to the receiver from power supply 92. The received signal is heterodyned in the first mixer 95 which is also coupled to an associated oscillator 96 to provide a signal for the first intermediate frequency amplifier 98. The signal is then further heterodyned by second mixer 101, which is coupled to an associated oscillator 103, and then the signal is applied to a filter, or series of tuned circuits, 105 to obtain selectivity in the receiver. The signal is further amplified by the second intermediate frequency amplifier 108 and applied to first limiter stage 110 and second limiter stage 112. Stages 110 and 112 provide well-known amplitude limiting of the angular modulation signal from transmitter 25. The output of second limiter 112 is applied to the discriminator 114 to derive modulation of the received carrier wave. This modulation includes the code tone signal as well as the audio signals from microphone 42.

The demodulated audio signals from discriminator 114 are applied through capacitor 116 to an RC compensating network 118 to provide a proper frequency relationship among the components of the audio signal as commonly required in an angular modulation system. The signal is then coupled to volume control 120 which may be adjusted to apply a portion of the signal through a shaping network 122 to the control grid of tube 124 in first audio amplifier 126.

Network 122 is designed to greatly attenuate low frequency audio signals below approximately 300 cycles in order to prevent the code tone from being translated by amplifier 126. A further filter network 128, in the form of a parallel-T filter is coupled to the anode, cathode and control grid of tube 124. This network includes resistor and capacitor elements which together are resonant at a frequency of approximately 350 cycles per second. Accordingly, network 128 in conjunction with compensating network 118 and shaping network 122 cause amplifier 126 to respond to audio signals above 300 cycles per second, while signals below this frequency are substantially cut off. These signals thus translated by amplifier 126 are applied to the second audio frequency amplifier 130 and after further amplification therein the audio signal is coupled to speaker 132 or any other suitable utilization means.

The receiver also includes a squelch control circuit 135 which regulates the conduction of tube 124 in the first audio frequency amplifier by applying or removing a cut-off bias potential to the control grid. The demodulated audio signals are applied to squelch circuit 135 by way of coupling capacitor 116 and resistor 137. These signals are amplified by tube 139, filtered by network 141 and fed to the control grid of tube 143. Capacitor 144 connected between the control grid of tube 139 and ground, together with low-pass filter network 141 provide attenuation of the voice audio signals and essentially allow only the audio tones below 300 cycles per second to reach tube 143. The output of tube 143 is coupled to vibratory resonant reed device 147 and this device is made resonant to the coded squelch tone regulated by reed device 75 at the transmitter (Fig. 2). It may be noted that a vibratory arm of device 147 will be set in motion upon reception of the code tone to alternately open and close contacts 149. Upon reception of a carrier signal the control grid of tube 151 in the second limiter 112 will draw grid current through resistor 152 and this voltage is applied by way of RC filter 154 to the control grid of tube 156 in the second audio frequency amplifier 130 thereby furnishing a bias for this tube. Furthermore, the negative voltage is coupled through filter 158 and contacts 149 to series-connected resistors 160 and 161.

The portion of this negative voltage appearing across resistor 161 is filtered by capacitor 162 and applied through resistor 163 to the control grid of tube 165. The cathode of this tube is normally grounded through switch 167 and the anode thereof is coupled through resistor 168 to a voltage divider comprising resistors 169 and 170 coupled between ground and B+. Tube 165, normally conductive with its grid grounded through resistors 161 and 163, is cut off or rendered non-conductive whenever reed device 147 is operated and the negative voltage from the second limiter 112 is applied to the control grid. When tube 165 is thus cut off, the potential at its anode rises to the potential existing at the junction of resistors 169 and 170. The junction of these resistors is coupled through resistor 168 and a D.C. path in filter network 128 to the control grid of tube 124 in the first audio amplifier 126. The cathode of tube 124 is returned through resistor 172 to the junction of resistors 169 and 170 and to ground through resistor 173 and switch 167. The values of the various circuit components and voltages are selected so that the tube 124 will conduct when tube 165 is cut off. Therefore, when the code tone is received to operate reed device 147, tube 124, which is otherwise cut off or rendered non-conductive by conduction of tube 165, will be conductive (the squelch circuit will be opened) and amplifier stages 126 and 130 will translate the demodulated signal appearing across a portion of volume control 120 so that it is heard from speaker 132. As previously pointed out the code tone will be removed by filter 122. Obviously, the receiver in Fig. 3 will respond only when the code tone to which reed device 147 is tuned, is received.

Switch 167 is included in the cathode circuit of tube

165 so that the tone operated squelch system may be disabled to enable the receiver to respond to all signals to which it is tuned regardless of whether the code tone is included therewith. When switch 167 is opened, tube 124 is conductive and the anode and cathode of tube 165 are coupled across resistor 172, with the cathode thereof more positive than the anode, so that tube 165 remains cut off.

It may be noted that audio tones of the order of 100–200 cycles per second are used to operate the tone coded squelch circuit 135 and that at such frequencies vibratory reed devices can be made highly selective. Therefore, many groups of stations may be included in the system of Fig. 1 and all may operate on the same carrier wave frequency while selective calling among the stations is effected by merely using reed devices of different response frequencies. It has been found that low frequencies of the order of 100–200 cycles per second are particularly effective in an angular modulation system because the squelch circuit may open even when the received carrier wave is of comparatively low strength. Obviously more than one reed device may be used in a transmitter or receiver so that any selective calling combinations are possible.

It may be noted that the vibratory reed of device 147 which opens and closes contacts 149 will have a certain finite size and weight and will therefore be subject to the effects of inertia. That is, once it is set in motion, it will continue to vibrate for a certain period even when the energizing tone has been removed. Thus, at the end of each transmission when the code tone and the transmitter carrier are no longer received contacts 149 may be alternately opened and closed for a period of up to one-third of a second which would keep the receiver squelch open for that time. With no carrier being received, the receiver would no longer be in a quieting condition and a short blast of noise would be emitted by the speaker. In the transmitter shown in Fig. 2 this is overcome by delaying the release of relays 47 and 18 to maintain transmission of the carrier as the reed of device 147 ceases to vibrate.

To provide this operation and maintain the receiver in a quieting condition since the carrier is being received with the squelch thereof opened, the following delay circuit is incorporated in the transmitter of Fig. 2. When push-to-talk switch 40 is opened, relay 44 is deenergized and contacts 70 are closed to ground the output of tone generator 72, so that resistor 66 is shorted and no tone will be applied to modulator tube 63. During the time relays 44 and 47 were energized, capacitor 180 remained charged through contacts 182 to the potential existing across relay 47 and resistor 46. When switch 40 has opened, charged capacitor 180 will maintain contacts 49 closed and relay 18 energized as it discharges, so that the carrier continues to be transmitted. When capacitor 180 discharges through resistor 46 and relay 47, this relay will release and relay 18 will release to stop transmission of the carrier. At this time a charge is maintained on capacitor 180 since the capacitor is connected across resistor 185 in voltage divider 185, 186 by contacts 187 of relay 47. This improves the system for rapid repeated use of the transmitter since capacitor 180 will have some charge when switch 40 is operated. Resistor 46 may be of a selected value to provide a desired delay in stopping the carrier so that the reed of device 147 in the receiver may come to rest and close the squelch of the receiver. Accordingly, by this carrier release delay system the blast of noise ordinarily emitted by the receiver due to inertia effects of reed device 147 will be overcome.

In the transmitter of Fig. 4, components corresponding generally to those of the transmitter of Fig. 2 are given the same reference characters. In this circuit, by closing push-to-talk switch 40, relay 44a is directly energized to close contacts 192 and energize relay 47a. Contacts

194 are also closed and these apply a signal from tone generator 72a to the control grid of modulator tube 63. With relay 47a energized, contacts 196 thereof close to energize relay 13 and render the transmitter operative so that the carrier is transmitted.

Tone generator 72a corresonds generally with tone generator 72 of Fig. 2 and, in the operated condition of push-to-talk switch 40, the output of the generator is derived from the anode of tube 78 through harmonic filter 85a. However, when switch 40 is released, contacts 192 will open and remove the operating potential from relay 47a which includes a slug 200 so that this relay is slow to release and opening of contacts 196 is delayed for a period of approximately 120 milliseconds. This maintains transmission of the carrier for that period. As soon as switch 40 is released, contacts 194 are opened and contacts 202 are closed which applies a tone from the anode of tube 77 to the control grid of modulator tube 63. The tone applied to contacts 202 is coupled from the anode of tube 77 by way of RC network 204. It is contemplated that the tone thus applied to the modulator when switch 40 is released be of the proper phase to damp the vibration of the reed device in the receiver in order to bring it to rest quickly. It may be noted that a tone of this phase will continually be applied to modulator 57 but that when the delay time of relay 47a has elapsed, relay 13 will be deenergized and the transmitter will not be operative.

Proper phasing of the signal to cause damping of the receiver vibratory reed device may be provided as shown in Fig. 5. It can be established that vibratory reed devices such as device 147 generally operate with the vibrating arm lagging the applied voltage approximately 45°. Accordingly, when the tone of reverse phase is applied to modulator 57 through lead 203, the signal should lead the previously applied tone by approximately 135°, so that the damping code tone will be 180° out of phase with respect to the motion of the vibrating arm of device 147. This will cause much more rapid closing of the squelch at the receiver and the time may be reduced to the order of 120 milliseconds to obtain closing of the squelch circuit. Thus, it is only necessary that the release of relay 47a to provide transmission of the carrier and the damping tone code of reverse phase be of the order of $\frac{1}{10}$ to $\frac{1}{5}$ of a second. It may be noted that the carrier of the transmitter will be received by the receiver during this period so that quieting action may take place while the reed device therein is being damped. The necessary 135 degree phase difference of signals in leads 205 and 203 is obtained by proper selection of constants in networks 85a and 204.

The invention provides therefore a two-way selective calling communication system which operates more quietly at the termination of each transmission. Provision is made to facilitate faster communication among stations of the system while at the same time operators of the equipment are not subjected to unnecessary noise during use of the apparatus.

I claim:

1. In a selective calling communication system including a wave signal receiver having a squelch circuit adapted to be opened upon reception of a carrier wave modulated by a tone of given frequency, which squelch circuit is operated by a resonant reed device subject to continuing vibration for a given period upon termination of energization thereof, a transmitter for said system including means for generating a carrier wave, modulating means for modulating the carrier wave with intelligence, tone generator means providing audio frequency tones of the given frequency including a first tone of a phase for operating the reed device with given motion and a second tone of a phase for damping said motion, first relay means having first and second contacts, said first relay means being operable to apply said first tone to said modulating means and being releasable

to apply said second tone to said modulating means, second relay means having third contacts for energizing said transmitter so that the carrier wave is transmitted, said second relay means including means for causing delayed release of said third contacts for a given period after deenergization thereof, and switch means operable to energize said first and second relay means for selective calling of the receiver and releasable to deenergize said first and second relay means with the delayed release of said third contacts providing transmission of the carrier wave for said given period modulated by said second tone, so that the carrier wave may be translated by the receiver to cause quieting thereof during damping of the reed device.

2. In a selective calling communication system wherein a wave signal transmitter is operative on a given frequency channel and wherein a wave signal receiver of a plurality of such receivers may be rendered responsive to signals from the transmitter, the combination including a receiver having a tone responsive squelch circuit adapted to be opened upon reception of a carrier modulated by a code tone of particular frequency, said squelch circuit including a vibratory resonant reed device actuated by the code tone for opening said squelch circuit, said reed device being subject to continuing vibration for a given period upon removal of the energization thereof, and a transmitter having means for generating a carrier wave, modulating means for modulating the carrier wave with voice intelligence, tone generator means providing first and second audio frequency tones of the particular frequency, said first tone being of a given phase to cause energization of said reed device and vibratory motion therein, said second tone being of a different phase to cause damping of said vibratory motion, first relay means energizable to apply said first tone to said modulating means and releasable to apply said second tone to said modulating means, said first relay means being releasable in less than said given period upon deenergization thereof, second relay means for energizing said transmitter so that a carrier wave is transmitted, said second relay means having delay means associated therewith for delaying release thereof during said vibratory motion, and a microphone for said modulating means including a push-to-talk switch for energizing said first and second relay means, whereby release of said push-to-talk switch provides the carrier wave modulated by said second tone during the continuing vibration of said reed device for damping thereof and closing of said squelch circuit.

3. In a communication system including a wave signal receiver having a squelch circuit adapted to be opened upon reception of a signal of given frequency, which squelch circuit is operated by vibrator means slow to release upon termination of the energization thereof, a transmitter for said system including a source of intelligence signals to be transmitted, switch means operable to a first position for transmission of the intelligence signals and to a second position for disabling said source of intelligence signals, signal generator means providing a signal of the given frequency including a first signal component having a phase for operating said vibrator means and a second signal component of a phase for damping said vibrator means, and circuit means connecting said signal generator means to said switch means for transmission of the first signal component in the first position of said switch means and transmission of the second signal component in the second position of said switch means so that the squelch circuit is opened upon transmission of the intelligence signal and closed in the absence of the intelligence signal.

4. In a selective calling communication system including a wave signal receiver having a squelch circuit adapted to be opened upon reception of a control signal of a given frequency, which squelch circuit is operated by resonant means which is slow to become deenergized on termination of the control signal to which it responds; a transmitter for said system including a source of intelligence signals to be transmitted, switch means operable to a first condition for transmission of the intelligence signals and to a second condition for disabling said source of intelligence signals, said switch further being momentarily operative through an intermediate condition upon operation from said first condition to said second condition thereof, signal generator means providing a control signal of the given frequency including a first signal component having a phase for energizing said resonant means and a second signal component having a phase for deenergizing said resonant means, and circuit means connecting said signal generator means to said switch means for transmission of the first signal component in said first condition of said switch means and transmission of the second signal component in said intermediate condition of said switch means so that said squelch circuit is opened upon operation of said switch means to said first condition for transmission of the intelligence signals and rapidly closed upon operation of said switch means through said intermediate condition.

5. A selective calling communication system including in combination, a wave signal receiver for a communication signal, said receiver having a squelch circuit operative by tuned means responsive to a control signal of given frequency and first phase for unsquelching said receiver and responsive to the control signal of given frequency and second phase for squelching the receiver; and a transmitter including means to provide a carrier wave, modulator means for modulating the carrier wave by intelligence signals, a signal generator operative to produce the control signal of given frequency and of the first and second phases, and switch means for controlling transmission of the modulated carrier wave by said transmitter and for selectively applying from said signal generator to said modulator means the control signal of first phase upon transmission of the intelligence signals and the control signal of second phase upon termination of transmission of the intelligence signals for rapidly squelching said receiver upon termination of transmission of the intelligence signals.

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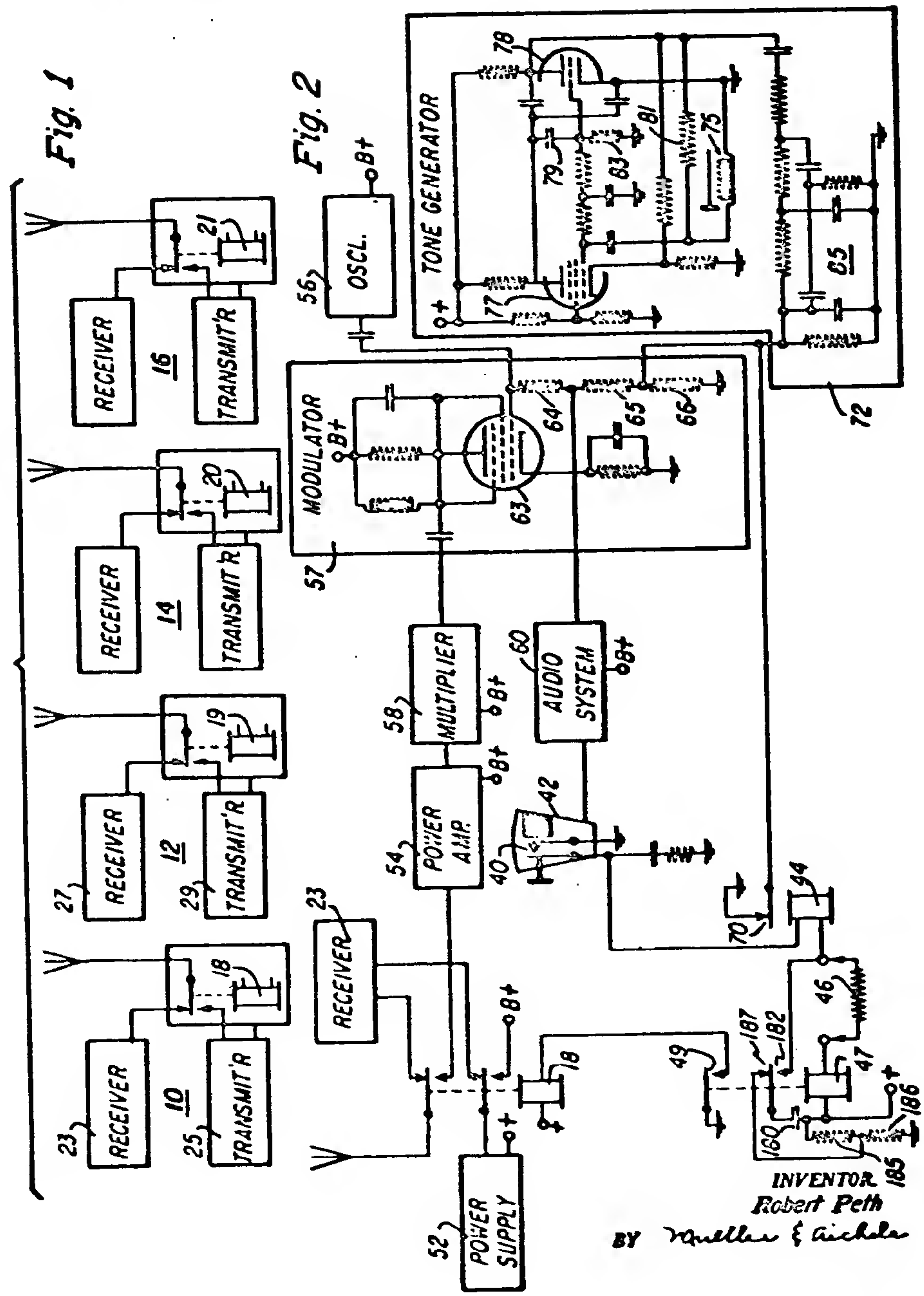
SQUELCH CIRCUIT

Filed Jan. 14, 1957 3 Sheets-Sheet 1



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SQUELCH CIRCUIT

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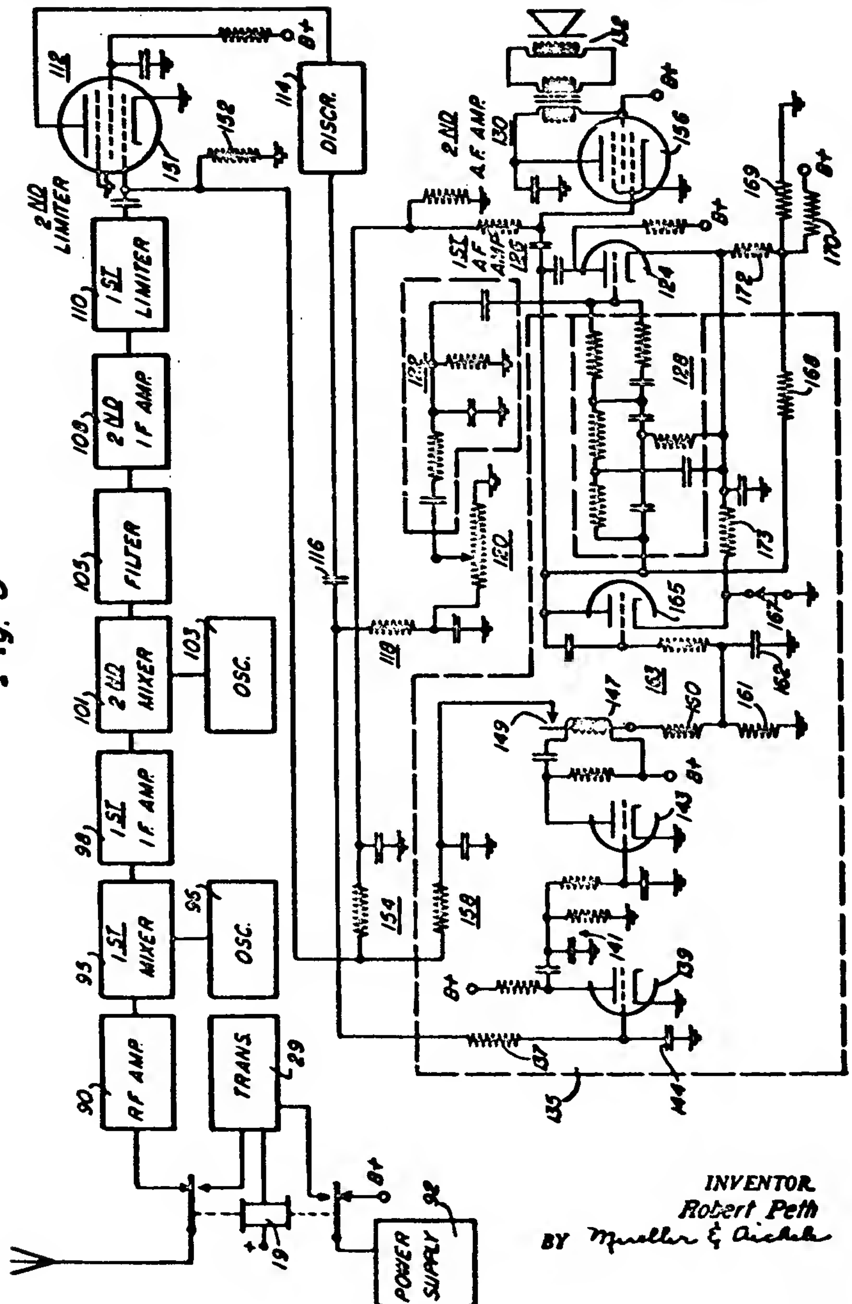
Fig. 3



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SQUELCH CIRCUIT

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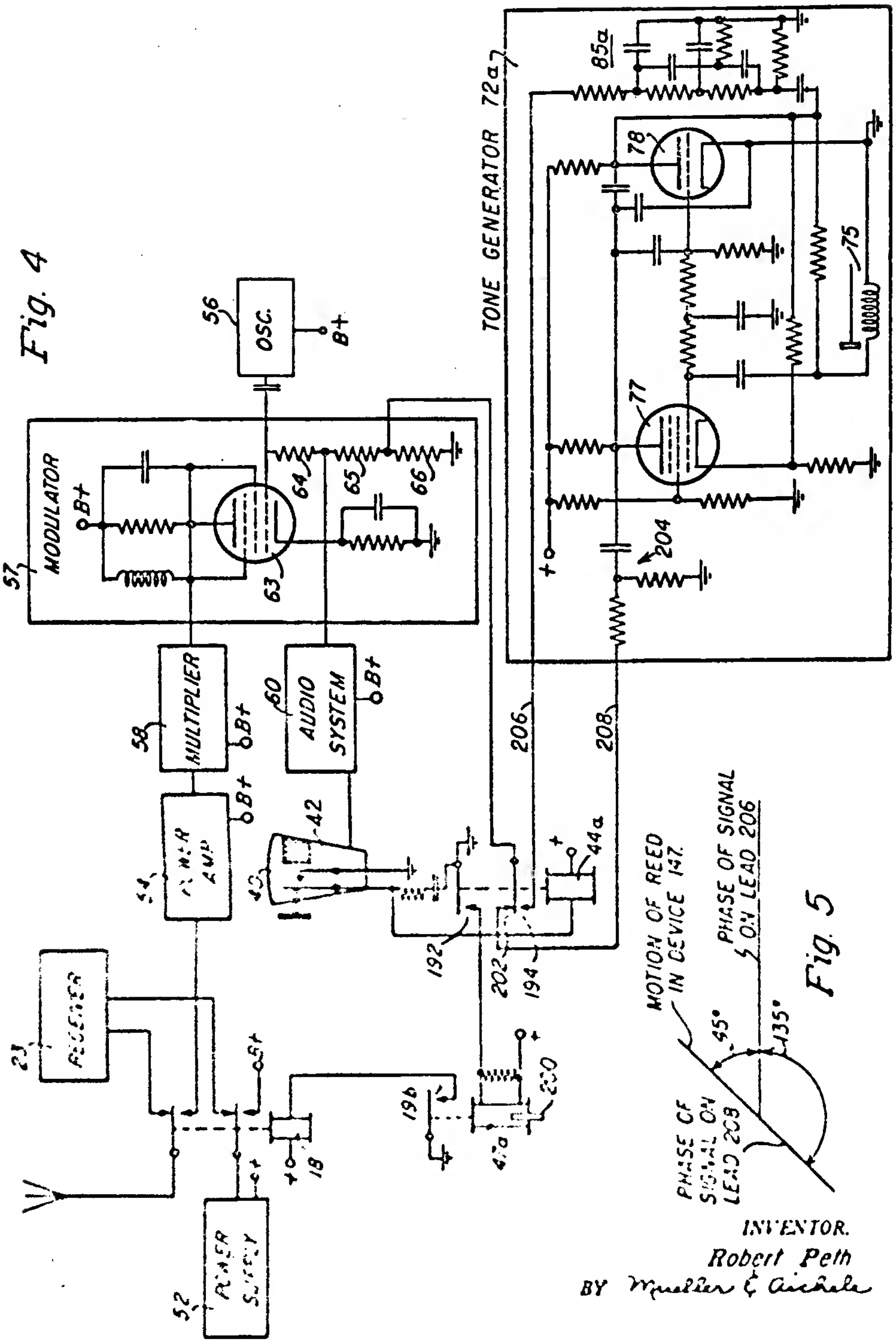

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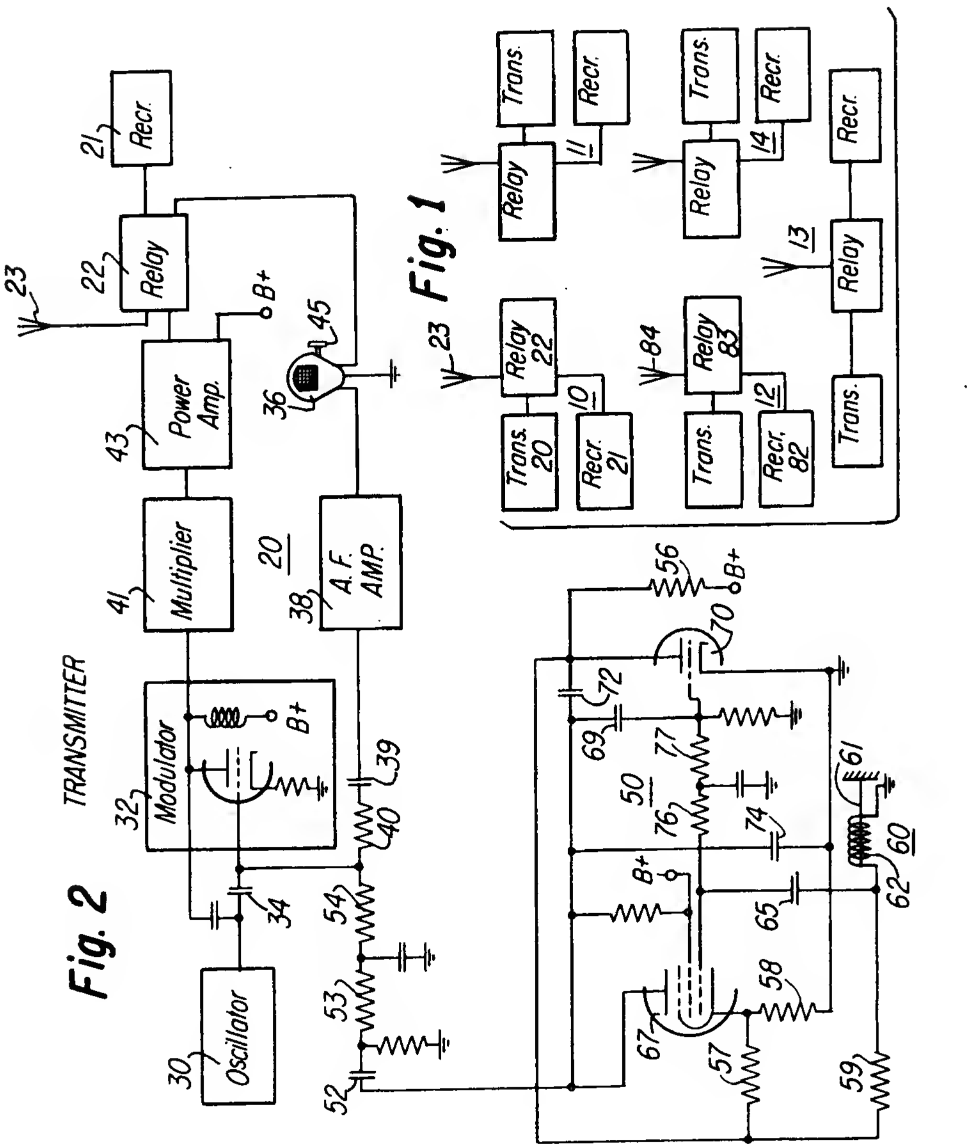
Dec. 22, 1959 R. PETH 2,918,571

COMMUNICATION SYSTEM

Filed July 25, 1958 3 Sheets-Sheet 1



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COMMUNICATION SYSTEM

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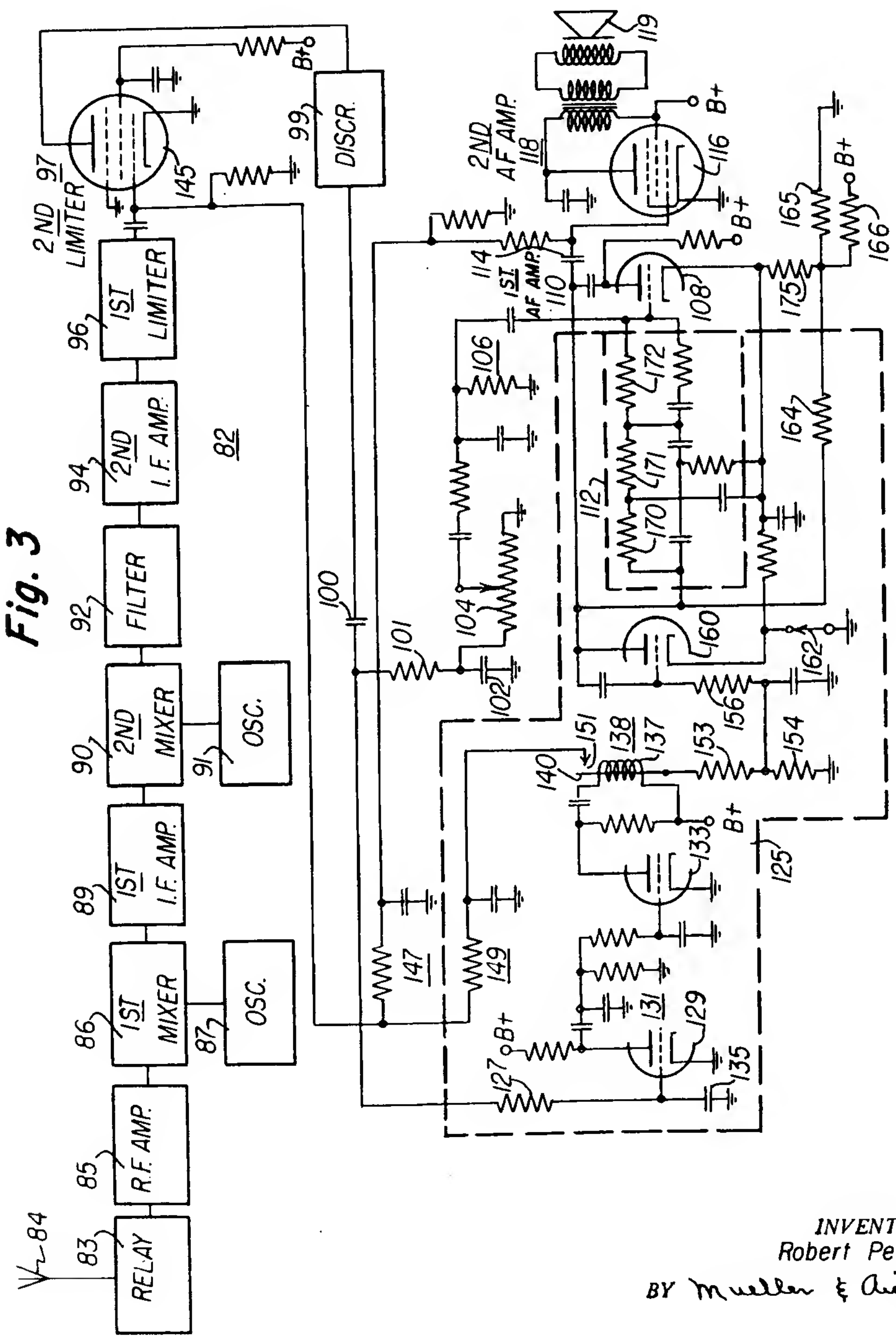

Fig. 3

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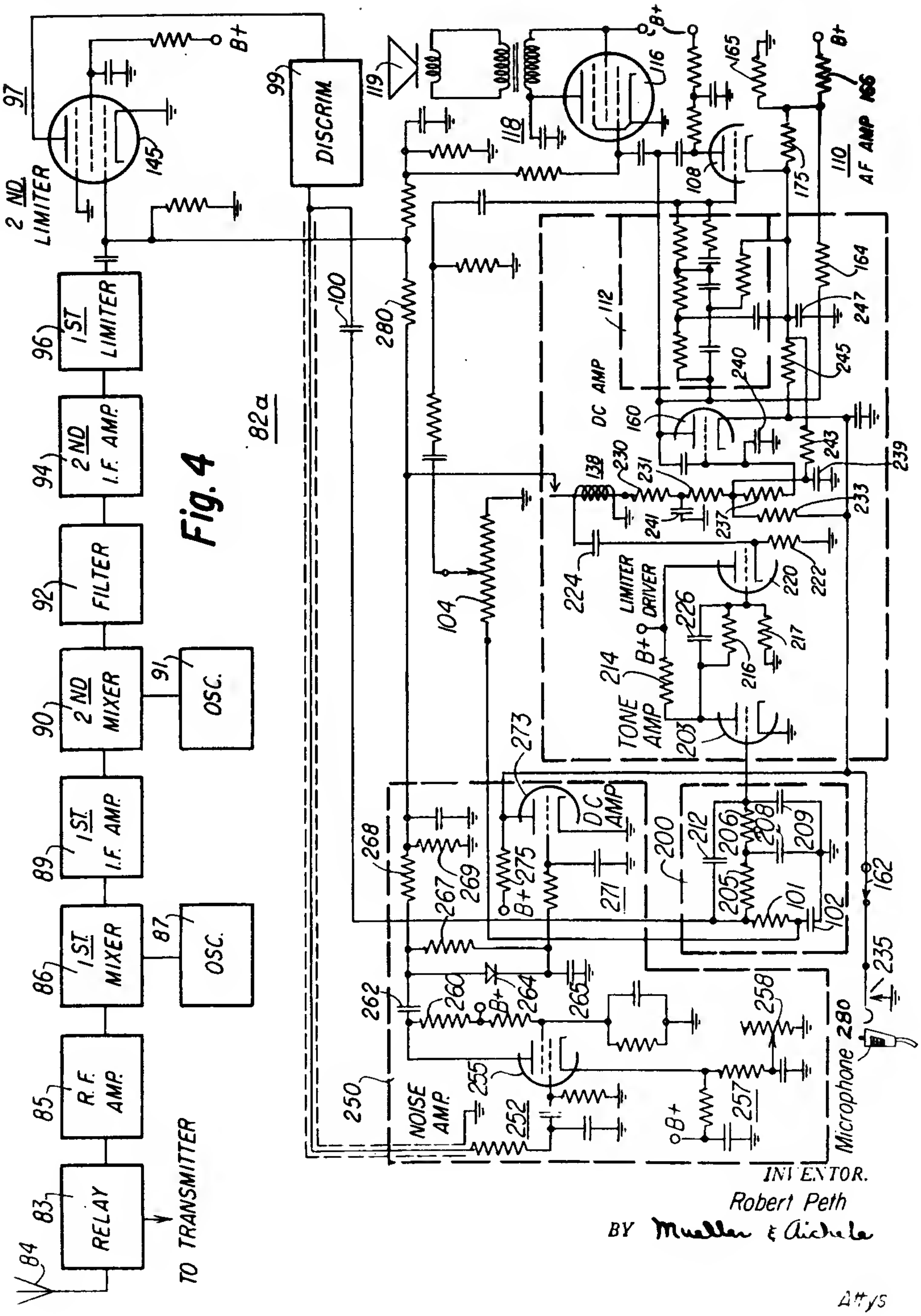

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2,918,571

COMMUNICATION SYSTEM

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Application July 25, 1958, Serial No. 750,977

13 Clams. (Cl. 250—6)

The present invention relates to communication systems and more particularly to wave signal equipment of the selective calling type. This application is a continuation-in-part of my copending application Serial No. 555,364, filed December 27, 1955.

Due to the rather extensive use made of the very high frequency radio communication channels and, therefore the crowded conditions at these frequencies, it is often necessary that different groups of communication stations operate on the same channel or wave length. Generally, in such a case, all the receivers within the power range of each transmitter will receive signals from that transmitter. While in some applications this may be permissible, and at times even advantageous, in many communication systems it is desirable that only certain receivers will reproduce signals from each transmitter, that is, that a selective calling provision be included so that a station will reproduce only signals having possible information for that station. This increases privacy in the system and, in the case of voice equipment, makes it unnecessary to hear signals of no concern to certain of the operators. Although selective calling equipment using tone signals of different frequency and squelch circuits in the receivers responsive to such tone has previously been used. This has generally been relatively complex and expensive and therefore not been altogether suitable for many applications.

In prior selective squelch systems a level control has been necessary for setting the squelch operating point at the receiver to obtain optimum squelch response to the tone signals without false responses on noise or undesired signals. The use of such a control is quite undesirable in communication equipment and is especially so in mobile 2-way communication equipment. It has also been necessary to maintain within close tolerances the modulation level of the tone at the transmitter in order that the sensitivity control setting at the receiver will not change. Furthermore, even with manual adjustment of the squelch operating point, difficulty may be experienced in effectively reducing response of the squelch system to noise signals and to maintain the system at a sensitive operating point for proper reception of relatively weak desired signals.

Accordingly, it is an object of this invention to provide a tone operated selective calling system which requires no sensitivity adjustment control at the receiver and a less critical tone modulation level at the transmitter.

It is also an object of the invention to provide a simple and reliable selective calling communication system so that only certain wave signal receivers in a plurality of receivers are responsive to a transmitted signal, and wherein there is reduced interference between different signals on the common channel and positive response by receiver to a desired signal.

It is another object to provide a tone operated squelch system which has high sensitivity to relatively weak desired signals and overall reduced sensitivity in the squelch system to noise signals in the absence of a desired signal, thereby reducing the tendency for false operation of the tone operated squelch system.

A further object is to provide a communication system wherein a plurality of transmitters and receivers are operative on the same carrier frequency and signals from a given transmitter are reproduced only by a specific receiver or receivers associated therewith, and wherein the operator of a receiver has a choice of rendering the receiver responsive to all the tansmitted signals or to only that of a given transmitter.

Still another object of the invention is to provide a communication system with a plurality of different transmitters and receivers wherein the receivers have tone operated squelch circuits to provide selective calling and in which the common communication channel for the transmitters is automatically monitored by an operator immediately prior to a transmission from that operator's station.

A feature of the invention is the provision of a system including a wave signal transmitter adapted to produce a carrier wave modulated by a specific tone frequency whenever the transmitter is operative, with the carrier wave also being modulated by intelligence, and an improved receiver having a squelch system with a resonant reed and driver circuit therefor which renders the receiver responsive only when a particular tone frequency is received thereby, so that another transmitter in the system transmitting the same carrier wave frequency which is modulated by a different tone frequency does not operate the receiver.

Another feature is the provision of a communication receiver adapted for selective calling and having a tone-operated squelch for rendering the receiver operative in response to a carrier wave modulated by the tone, with the squelch including a resonant reed responsive to the tone to bias to cut off a control tube in the audio frequency system of the receiver and render the audio system operative.

A further feature of the invention is the provision of a tone operated squelch circuit with a frequency selective reed responsive to a tone of particular frequency and a limiter stage to apply signals of fixed level to the reed and a filter network providing the input signals to the limiter stage for reducing possible false response of the squelch circuit to noise components in the absence of a desired signal.

Another feature of the invention is the provision of such a filter network and limiter driver stage for a frequency responsive reed wherein the filter network reduces the level of signals in the voice communication frequency range to increase the relative level of signals in the control tone range for improving the reed response to a squelch operating tone.

A still further feature is the provision of a tone operated squelch circuit combined with a noise-carrier operated squelch circuit and means for rendering one or the other of the squelch circuits operative in a communication receiver, including a switching circuit for automatically rendering the noise-carrier squelch operative when the station microphone is removed from its cradle in order to automatically monitor the communication channel prior to transmitting.

Further objects, features and the attending advantages thereof will be apparent upon consideration of the following description when taken in conjunction with the accompanying drawings in which:

Fig. 1 is a diagram of a plurality of communication stations which incorporate the invention;

Fig. 2 is a block and schematic diagram of a transmitter incorporating the invention;

Fig. 3 is a block and schematic diagram of a receiver incorporating the invention; and

Fig. 4 is a block in schematic diagram of a receiver incorporating a further form of the invention.

The invention provides a selective calling communication system wherein a plurality of transmitters and receivers are operative on the same carrier frequency and a transmitter automatically renders only certain receivers responsive to signals therefrom. The transmitters are arranged, whenever operated, to send a carrier wave which is modulated by a tone signal of certain low frequency, and to transmit intelligence by further modulation of the wave. The receivers in the system each include a tone-operated squelch and become operative only when a carrier wave is received which is modulated by a given tone. Thus, only receivers responsive to the tone signal modulating the carrier wave of a particular transmitter will respond to reproduce the intelligence sent by that transmitter.

The receivers incorporate a resonant reed device in the audio frequency system so that modulation of a received signal at the reed frequency causes the same to apply a cut-off bias potential to a control tube in the audio system. A cut-off condition of this tube removes a cut-off bias potential on an audio amplifier tube in the receiver, in order that modulation comprising the intelligence may be translated. A convenient frequency range for the resonant reed is between 100–150 cycles per second since these frequencies may be removed from the audio without affecting intelligibility. It is contemplated that a filter will be used to remove the tone signal from the intelligence as translated by the audio frequency channel.

The invention may also include a frequency responsive reed driven by squelch control signals applied to a filter network and limiter stage so that in the presence of a control tone a fixed level drive for the reed maintains constant bandwidth for the control tone and obviates the need for a squelch level setting control. This fixed drive further permits non-critical modulation requirements for the control tone at the transmitter. For example, it is thus unnecessary to establish at a precise fixed level the modulation deviation of the control tone in order to properly operate the receiver squelch at its control setting.

The filter network passes signals in the frequency range of the reed and in the higher frequency noise band to take advantage of the FM noise improvement for reducing the random noise energy applied to the reed in the no signal condition and for increasing the response to signals in the tone frequency range in the presence of a carrier signal. The operation of this portion of the invention will be described in greater detail in connection with the circuit of Fig. 4.

The tone operated squelch system may also be combined with a noise-carrier operated squelch so that a user of the communication receiver has a choice of which type of squelch system may be preferable at any particular time. The system may also be arranged for automatic operation in the noise-carrier squelch mode prior to transmission from a particular station in order to provide monitoring of all stations common to the communication channel to determine that the channel is clear before beginning a transmission.

Considering now a specific form of the invention, reference may be had to Fig. 1 which shows a communication system with two-way communication stations **10**—**14**. Stations **10** and **11** may be considered base stations which are operative on the same wave length or carrier frequency. Station **10** is typical of those in the system, which may all be constructed alike, and includes a transmitter **20**, a receiver **21** and a relay **22** which selectively couples either the transmitter or the receiver to antenna **23**. In the example of the invention being described it may be assumed that base station **10** can inter-communicate with mobile stations **12** and **14** to the exclusion of station **13** and that the transmitter of station **11** will communicate with mobile station **13** and will not be heard at the receivers of stations **12** and **14**. Various system arrangements may of course be used and the above is merely an example.

Fig. 2 shows the transmitter **20** in greater detail. This transmitter includes an oscillator **30** which feeds a modulator **32** through capacitor **34**, the modulator providing angular modulation of the carrier wave from the oscillator. The modulator shown is of the phase modulation type. Audio frequency signals from microphone **36** are amplified in the audio frequency amplifier **38** and applied through capacitor **39** and resistor **40** to the modulator **32**. The modulated signal is then applied to a multiplier **41** which raises the frequency of the signal. The modulated signal is coupled to amplifier **43** which provides a modulated signal of the necessary power for the desired communication purposes. Microphone **36** includes a push-to-talk switch **45** which may be operated to energize relay **22**, the contacts of which (not shown) apply the signal from amplifier **43** to the antenna **23**.

The transmitter **20** further includes an audio oscillator **50**, or source of tone signals, also coupled to the modulator **32** to continuously modulate the carrier wave whenever the transmitter is operative. This tone signal is coupled to modulator **32** by way of blocking capacitor **52** and resistors **53**, **54**. In oscillator **50**, a voltage divider, including resistors **56**, **57** and **58** provides a D.C. starting potential applied through resistor **59** to a resonant reed **60**. Reed **60**, which has a vibrating arm **61** movable in a coil **62** at the natural frequency of the arm, controls the frequency of the audio signal through capacitor **65** and the control grid of pentode tube **67**. The anode of tube **67** is coupled through blocking capacitor **69** to the control grid of triode tube **70**. Accordingly, a signal, the frequency of which is controlled by resonant reed **60** is amplified in tube **67** and applied to tube **70**. A portion of the output of tube **70** is coupled, by way of resistor **59** and capacitor **65** in order to sustain oscillation in the system. Furthermore, for increased stability there is a certain amount of inverse or negative feed-back in oscillator **50** due to the intercoupling of the control grids of tubes **67** and **70** by way of resistors **76** and **77**. Additional negative feed-back for stabilizing the circuit is also provided by the intercoupling of the anode of tube **70** to the grid thereof by way of capacitors **72** and **69**. Accordingly, the output of audio oscillator **50** is a highly stable tone signal which is applied to modulator **32**. In a preferred form of the invention, the frequency of the tone signal furnished by oscillator **50** may be in the range of 100–150 cycles which is below the range necessary for voice communication purposes in many applications.

Fig. 3 shows in some detail the circuit arrangement of the receiver **82** of mobile station **12** in Fig. 1. Radio frequency amplifier **85** includes a connection to relay **83** through the contacts of which antenna **84** is coupled to amplifier **85**. Radio frequency amplifier **85** selects and amplifies a received signal and applies the same to the first mixer **86** to which is also connected an oscillator **87**. The received signal is heterodyned in first mixer **86** and converted to a signal of intermediate frequency. This signal is applied to first intermediate frequency amplifier **89** where it is further selected and amplified after which it is coupled to second mixer **90**. Oscillator **91** is also coupled to second mixer **90** and in this mixer circuit the signal is heterodyned and converted to a lower intermediate frequency signal which is fed to the filter **92**. Filter **92** provides high selectivity for signals applied thereto and the signal thus selected is coupled to the second intermediate frequency amplifier **94**. After fur-

ther amplification in amplifier **94** the signal is applied successively to first and second limiters **96, 97** in order to remove substantially all amplitude variations thereof. The output of second limiter **97** is applied to the demodulator or discriminator circuit **99** where modulation of the received signal is derived. These demodulated signals would, of course, comprise a tone signal from oscillator **50** in the transmitter of station **10**, as well as any speech signals obtained from a microphone at that station.

The voice or audio frequency signals from discriminator **99** are coupled by way of capacitor **100** to a network comprising resistor **101** and capacitor **102** in order to reduce the high frequency audio signals as commonly required when operating with a phase modulation transmitter, thus tending to provide a proper frequency relationship among the components of the audio signal. The signal is then coupled to a volume control or variable resistor **104** which may be adjusted to apply a given portion of the audio voice signal through a high pass filter network **106** to the control grid of triode tube **108** in the first audio amplifier **110**.

Network **106** includes resistor and capacitor components tending to greatly attenuate the low frequency audio signals below 300 cycles in order to prevent the tone signal from being translated by the amplifier **110**. An additional filter network **112** is coupled to the anode, cathode and control grid of triode **108** and this network is one which may be described as a parallel-T filter. Network **112** includes resistor capacitor combinations which altogether are resonant at a frequency of approximately 350 cycles per second. Accordingly network **112** in conjunction with network **106** provide a frequency response at the input to amplifier **110** which passes audio signals above the frequency of 300 cycles per second and substantially cuts off audio signals below that frequency. Audio signals amplified by triode tube **108** are applied through coupling capacitor **114** to the pentode tube **116** in the second audio amplifier **118**. After further amplification in tube **116** the signal is then applied to loudspeaker **119**, or any other utilization means.

Receiver **82** also includes a squelch control circuit **125** which regulates the conduction of tube **108** in the amplifier **110** by applying a cutoff bias potential to the grid of tube **108**. Control circuit **125** receives the demodulated audio signals by way of coupling capacitor **100** and resistor **127**. The audio signals are applied to the control grid of triode tube **129**, and after amplification by this tube the signals are applied through filter network **131** to the control grid of triode tube **133**. Capacitor **135**, connected between grid and cathode of tube **129** together with low pass filter network **131**, provide attenuation of the voice audio signals and in effect pass essentially the audio tones below 300 cycles per second. The output from tube **133** is coupled to coil **137** of resonant reed **138**. Accordingly, when an audio tone of the frequency at which reed **138** is resonant is translated by the receiver, arm **140** of reed device **138** is driven as a vibrator. Furthermore, when a signal is being received by receiver **21**, pentode tube **145** in the second limiter **97** will draw grid current through its grounded cathode as it performs its limiting function and a negative voltage with respect to ground will be available at the control grid of this tube. This negative voltage is applied by way of RC filter circuit **147** to the control grid of pentode tube **116** in amplifier **118** thus furnishing a bias for this tube. In addition, this negative control voltage is coupled by way of filter circuit **149** to a fixed contact **151** of reed device **138**. The movable arm **140** of this reed device is coupled through resistors **153** and **154** to ground. Thus, it may be seen that as reed device **138** is energized a portion of the negative voltage appearing at the grid of tube **145** will appear across resistor **154**.

The negative voltage so developed across resistor **154** is applied through resistor **156** to the control grid of triode tube **160**. The cathode of tube **160** is normally grounded through switch **162** and the anode thereof is coupled through resistor **164** to a voltage divider consisting of resistors **165** and **166** coupled across the B+ potential source. The potential thus applied to the anode of tube **160** is such that this tube is cut off or rendered nonconductive whenever reed device **138** is energized and the negative voltage from the limiter stage is applied to the grid of tube **160**. Accordingly, as tube **160** is nonconductive the potential at its anode will rise substantially to the value of the potential existing at the junction of resistors **165, 166**. The junction of these resistors is also coupled through resistor **164** and a D.C. path in filter network **112**, namely resistors **170, 171** and **172**, to the control grid of tube **108** in audio amplifier **110**. The cathode of tube **108** is returned through resistor **175** to the junction of resistors **165, 166**. Resistor **175** therefore provides a cathode bias for tube **108** and the values of the various circuit components are selected so that tube **108** is in a conductive state when the potential at the junction of resistors **165, 166** is applied to the control grid thereof. Therefore, it may be seen that under such conditions the audio signals from discriminator **99** will be translated by amplifiers **110** and **118** and applied to speaker **119** to be reproduced thereby. Furthermore, the audio tone signal is filtered out by network **106**, as previously described above, so that only the speech, and not the tone signal, will be reproduced by the speaker.

It should be obvious from the description given that if a tone signal of the frequency to which reed device **138** is responsive is not included in the modulation of a received signal, the negative control voltage will not be applied to cut off tube **160** and that this tube will conduct thus lowering the voltage appearing at its anode to an extent sufficient to bias tube **108** in amplifier **110** below its cutoff point. Accordingly, no audio signals will be translated by this amplifier stage. Therefore, signals from some other transmitter operative on the same carrier wave frequency to which receiver **82** is tuned will not be reproduced thereby. For example, if the transmitter of station **11** of Fig. 1, is transmitting a signal including modulation at a different tone frequency than the one to which reed device **138** is responsive, the voice signals therefrom will not be reproduced by speaker **119**. That is, under such conditions the squelch control circuit **125** will not be opened to render the receiver responsive to that signal.

Switch **162** is included in the cathode to ground circuit of triode tube **160** so that the tone-operated squelch circuit **125** of the receiver may be disabled thus rendering the receiver responsive to reproduce all signals regardless of whether such signals include the audio tone to which reed device **138** is tuned. When switch **162** is open, the tube **160** will be cut off since the anode thereof is coupled to the junction of resistors **165, 166** and the cathode thereof is coupled to the cathode of tube **108** which is at a potential slightly higher than that existing at the junction of resistors **165, 166**, that is, its cathode is at a higher potential than its anode. With tube **160** cut off, of course, the bias potential on the grid of tube **108** is such that this tube is operative to translate audio signals in the receiver.

Fig. 4 is a block and schematic diagram of the receiver **82*a*** which corresponds in part to the receiver **82** of Fig. 3. Portions of the receiver **82*a*** which function the same as those of receiver **82** are given the same reference characters.

In this form of the receiver, the demodulated audio, or voice signals are coupled from the discriminator **99** and through capacitor **100** and the de-emphasis network **101, 102** in the band reject filter **200**, to the volume control **104**. The variable arm of the volume control is coupled by way of an RC network to the control grid of triode **108** in the first audio amplifier **110**. The signals which are amplified in the triode **108** are then applied to

tube 116 and to the speaker 119. As is the case of the circuit of Fig. 3, the triode 108 is rendered operative when the direct current amplifier triode 160 is cut off and this is accomplished by the reception of a control tone to which the resonant reed 138 is tuned.

The demodulated signals from discriminator 99 are applied to the hand reject filter 200 and from the output of this filter to the control grid of the tone amplifier triode 203. Filter 200 in addition to including the deemphasis network 101, 102 comprises series connected resistors 205, 206 and shunt connected capacitors 208, 209 forming a low pass filter section of the network. Capacitor 212 is connected across resistors 205 and 206 to modify the response of the filter and couple through a portion of the higher frequencies.

The values of the components in the hand reject filter 200 are chosen so that low frequency signals in the range to approximately 300 cycles are passed with high amplitude and signals in the range from 300 to approximately 1,000 cycles are substantially rejected. The response of the filter does, however, increase at the higher frequencies for signals beyond 1,000 cycles and in this range and higher, the response is substantial but somewhat less than in the low frequency range to 300 cycles. In summary the filter 200 provides high level conduction of the signals in the tone frequency range, substantial attenuation of the lower frequency voice range and medium level conduction of signals in the higher frequency voice communication range and in the higher frequency range of noise components.

The tone amplifier triode 203 has a grounded cathode and the signals are applied to the grid with respect to ground. The anode of this tube is connected to B+ through the load resistor 214. The anode is also connected to the resistors 216 and 217 which are series coupled to ground thereby forming a voltage divider between B+ and ground. Triode 220 is coupled in a limiter stage for driving the resonant reed 138. The control grid of tube 220 is connected to the junction of resistors 216, 217 and the anode thereof is connected directly to B+. The cathode of triode 220 is connected to ground through the load resistor 222. The coil of the reed 138 is coupled between ground and the cathode side of resistor 222 by means of blocking capacitor 224.

It may be noted that the control grid of triode 220 in the limiter stage is direct current coupled to the anode of tone amplifier triode 203. A capacitor 226 is connected across resistor 216 and, in the no-signal condition, the triode 220 will be biased according to its grid conduction and the bias provided by the cathode resistor 222. As signals are applied to this limiter driver stage the triode 220 provides limiting action and a fixed level drive for the reed 138.

As in the circuit of Fig. 3 the potential to cut off the direct current amplifier 160, for rendering the audio stage 110 operative, is provided by the limiter 97. This negative potential produced upon reception of a signal is applied through the contacts of the reed 138 and is developed across the series combination of resistors 230, 231, and 233. Resistor 233 is grounded through the switch 162 and contacts 235. That portion of the negative grid potential appearing across resistor 233 is applied through the series resistor 237 to the control grid of the direct current amplifier triode 160. Resistors 230, 231 and 237 together with bypass capacitors 239, 240 and 241 form a filter for the pulsating potential produced by the contacts of the resonant reed. Resistors 237, 243 and 245 form a grid leak path back to the cathode of the triode 160. Filter capacitor 247 connected between ground and the junction of resistors 243 and 245 bypasses this portion of the circuit for alternating currents.

In the tone operated squelch circuit of Fig. 4, triode 220 provides limiting of the driving signals for the reed 138 and this maintains a constant band width of response of the reed device, since the amplitude of the signals is constant. This fixed drive of the reed gives improved operation thereof and a more positive response to the control tone. Furthermore, with a limiter driver it is unnecessary to have a level setting control in the tone operated squelch circuit since the level of the driving tone signals for the reed are constant. In other systems, requiring a level setting control, it is necessary to adjust the tone amplification to be sufficient to insure operation of the tone responsive device but yet not too great to provide a wide energy band in which signals other than the particular signal to which the reed is tuned would have enough energy to cause false operation of the resonant reed. Furthermore, with a particular setting of a level control at the receiver, the tone modulation at the transmitter must be maintained constant. For example, the deviation of the control tone at the transmitter in an FM system would have to be maintained within close tolerances unless the level setting at the control of the receiver were readjusted to compensate for a change in deviation at the transmitter. However, by using the circuit of Fig. 4 the tone modulation is not critical and the constant drive provided by the limiter stage is unaffected by changes in transmitter modulation level.

The characteristics of the hand reject filter 200 also play an important role in preventing false response of the resonant reed while insuring a more sensitive response in the presence of the tone of proper frequency. In a no-signal condition, the filter passes both low frequency and high frequency energy and these signals are limited to a small degree by the limiter stage so that there is a comparative reduction in the low frequency energy band (in the range of the squelch tone signals) over what would be the case in the absence of the higher frequency energy. However, when a signal is received, the noise energy is reduced due to the FM quieting action and this causes a relative increase in the energy available in the lower frequency or control tone range. This then has the effect of increasing the noise immunity of the tone operated squelch without detracting from the sensitivity thereof to the desired tones. Accordingly, with the filter network and limiter drive for the reed, it is possible to use enough power in the control tone modulation of the carrier to take advantage of the squelch selectivity to the tone and the speed of response thereto (by using short time constants in the R–C circuits for the tone signal circuits), while maintaining relatively high noise immunity or desirable falsing characteristics for the resonant reed.

In the circuit of Fig. 4 there is also shown a noise-carrier squelch circuit 250 which can be rendered operative to unblock the audio amplifier in response to reception of a carrier wave regardless of whether the wave is modulated by a control tone. In this circuit, the output of the discriminator 99 is applied through a high pass filter 252 to the control grid of the noise amplifier tube 255. The cathode of tube 255 is connected to a voltage divider 257 connected between ground and B+ and this voltage divider includes a variable resistor 258 for setting the cathode bias of the tube 255. This forms a sensitivity control to establish the level at which this squelch circuit will operate. A load resistor 260 is connected between the anode of tube 255 and B+ and the output noise signals from tube 255 are applied by way of blocking condenser 262 to the anode of diode 264. The cathode of this diode is connected to ground through capacitor 265. Series connected resistors 267, 268 and 269 are coupled across capacitor 265 as the diode load resistors. The cathode of the diode is connected through a low pass filter 271 to the control grid of a D.C. amplifier triode 273. The cathode of triode 273 is grounded and the anode is connected to B+ through a load resistor 275.

In the absence of a carrier signal, a positive voltage is developed across capacitor 265 by the noise rectified by the diode 264 and this causes increased conduction of triode 273. With either switch 162 or contacts 235 opened, the anode of triode 273 will be ungrounded and

this electrode is coupled directly to the cathode of direct current amplifier **160**. With the increased conduction of tube **273** due to rectified noise, the anode potential thereof will decrease and lower the cathode potential of triode **160** thereby causing this tube to remain in conduction and block the first audio triode **108**.

When a carrier signal is received, the noise level decreases due to the FM quieting characteristics and the potential of the grid of triode **273** is reduced. Furthermore, the junction of resistors **268** and **269** is connected through isolating resistor **280** to the control grid of the tube **145** in the second limiter **97**. Therefore, the same negative potential available at the grid of this limiter that is used to cut off the triode **160** is also applied to the control grid of triode **273** to cause greatly reduced conduction of this tube. This causes a rise in the anode potential of triode **273** and a corresponding rise in the cathode potential of triode **160**, thereby cutting off this triode and unblocking the first audio stage **110**.

The carrier responsive squelch circuit **250** can be rendered operative by opening switch **162**. It can also be rendered operative by opening of contacts **235** which are ordinarily closed when the transmitter or microphone **280** is positioned on its cradle and is therefore not in use. However, when the microphone, which ordinarily has a push-to-talk switch and is similar to microphone **36** in Fig. 2, is picked up preparatory to transmitting, the common communication channel among all of the various stations in the selective calling system can be monitored automatically since the carrier operated squelch will function to unblock the audio system for any carrier signal that is being transmitted regardless of the code tone with which it may be modulated. It should also be apparent that a dual squelch system of this type would find utility in a system of two-way stations in which only some of the stations utilize a tone coded squelch.

It should also be pointed out that audio tones of the order of 100–200 cycles per second are used to operate the tone responsive squelch circuits and that at such frequencies reed devices such as resonant reeds **138** and **60** (Fig. 2) can be made highly selective. Therefore, many groups of stations may be included in a system having a common carrier wave frequency while still maintaining exclusive communication between selected ones of the stations by merely utilizing reed devices of different response frequency in the various transmitters and receivers. Furthermore, it has been found that low frequencies of the order of 100–200 cycles per second may be received and translated by an angular modulation receiver and cause opening of the squelch control circuit thereof even when the carrier wave modulated by such a signal is of comparatively low strength. Therefore, this system provides selective calling among various communication stations wherein rather weak signals may be received to operate selectively desired ones of the receivers in the entire system.

Since it is common to include some type of a squelch circuit in comunication receivers for two-way use, to incorporate the selective calling provision of the present invention in the squelch system adds but few additional components while still keeping the system of simple construction. Furthermore, it should also be obvious to those skilled in the communication art that the transmitter may include several audio tone oscillators operative at different frequencies in order to selectively call different receivers in a system and that various receivers in the system may include more than one frequency resonant reed device in order to be responsive to more than one transmitter in the system. In such a case, the reed devices could merely be connected in parallel so that operation of any one of the same would render the receiver responsive. Also various combinations of carrier wave frequencies and selective calling provisions can be used among the transmitters and receivers of stations such as the base and mobile stations of Fig. 1 in order to effect desired communication with necessary or advantageous privacy.

In practical operation of systems using the invention it has been found unnecessary to include specific circuitry in the transmitter to prevent transmission through the microphone of tones to cause "false" operation of a receiver. The general high selectivity of the resonant reeds and attenuation of low frequency signals in speech amplifier circuits at the transmitter have been effective in preventing such false operation.

I claim:

1. In a selective communication system wherein a plurality of wave signal transmitters are operative on a given wave length and wherein a wave signal receiver of a plurality of such receivers may be rendered responsive to signals from a given transmitter, the combination including an angular modulation transmitter having means for generating a carrier wave, means including a resonant reed device for simultaneously modulating the wave with an audio tone of selected frequency regulated by said reed device and with an intelligence signal of a frequency range higher than said selected frequency; and an angular modulation receiver having means for demodulating the carrier wave, said receiver having an amplifier for translating the demodulated intelligence only when a control is applied thereto, said amplifier including filter means in the input thereof for rejecting said audio tone, and a squelch control circuit adapted to apply said control to said amplifier when said audio tone is applied thereto by said means for demodulating the carrier wave, said squelch control circuit including amplifier means, further filter means coupled between said means for demodulating the carrier wave and said amplifier means, said further filter means being adapted to reject signals in the frequency range of the intelligence signal, a resonant reed device turned to said selected frequency and energized by said amplifier means to render said squelch control circuit operative so that said squelch control circuit is responsive only to said tone of selected frequency and an intelligence signal of a carrier wave, modulated by a tone of different frequency will not be translated by said amplifier.

2. In a selective communication system comprising a plurality of wave signal transmitters and wave signal receivers, the combination including a transmitter having means for generating a carrier wave phase modulated simultaneously by intelligence and by an audio tone of selected low frequency; and a receiver for demodulating the carrier wave, said receiver having a source of negative potential and an amplifier for the demodulated intelligence which amplifier is inoperative when a control potential is applied thereto and operative when said control potential is removed, said receiver further having a control circuit including an electron discharge device adapted to conduct and apply a control potential to said amplifier and to be nonconductive to remove said control potential, said control circuit including amplifier and low pass filter means for translating the audio tone and a resonant reed device coupled to said amplifier to be operated by a demodulated audio tone of said selected frequency, said reed device having contacts to apply said negative potential to said electron discharge device to render the same nonconductive when an audio tone of said selected frequency is present for causing said amplifier to be operative.

3. In a selective communication system wherein a plurality of wave signal transmitters are operative on a given carrier wave frequency and wherein a wave signal receiver of a plurality of such receivers may be rendered responsive to signals from a predetermined transmitter, the combination including a transmitter having means for generating a carrier wave, means for phase modulating the wave with intelligence and for simultaneously phase modulating the carrier wave with an audio tone of selected frequency below that of the intelligence; and a receiver for

demodulating the carrier wave, said receiver having a limiter stage therein providing a source of negative potential and an amplifier for the demodulated intelligence which amplifier is inoperative when a control potential is applied thereto and operative when said control potential is removed, said amplifier having a high pass filter for rejecting the audio tone, said receiver further having a squelch control circuit including a control tube adapted to conduct and apply a control potential to said amplifier and to be nonconductive to remove said control potential, said squelch control circuit also including amplifier means responsive to the audio tone and a resonant reed device driven by said amplifier means and coupled to the receiver and constructed to be operated by a demodulated audio tone of said selected frequency, said reed device having contacts to apply said negative potential to said control tube to render the same nonconductive when an audio tone of said selected frequency is present for causing said amplifier in said receiver to be operative.

4. In a selective communication system wherein a plurality of wave signal transmitters and receivers are operative on a given carrier wave frequency, the combination of transmitter means adapted to transmit a carrier wave phase modulated by audio signals in a first range above 300 cycles per second and phase modulated by a narrow band audio tone signal in a second range between 100 and 150 cycles per second; and receiver means for demodulating said carrier wave including a discriminator for deriving said audio signals and said tone signal, an audio amplifier including a first electron discharge device subject to cut off by a bias potential, a filter network constructed to pass said first range coupling said discriminator to said audio amplifier, a tone operated squelch circuit including a resonant reed device, an amplifier and filter network constructed to pass said second range coupled between said discriminator and said resonant reed device, means supplying a negative control potential, said squelch circuit including a second electron discharge device having control and output elements, said resonant reed device having contacts to apply said negative control potential to said control element of said second electron discharge device and to cause nonconduction thereof in the presence of said tone signal, circuit means coupling said output element of said second discharge device to said first electron discharge device to apply a cut off bias potential thereto when said second discharge device conducts and to remove said cutoff bias potential and render said audio amplifier responsive when said second electron discharge device is nonconductive.

5. In a selective communication system, a receiver responsive to a carrier wave phase modulated by intelligence in a first frequency range and by a narrow band audio tone signal in a second frequency range below said first range, said receiver including in combination, a discriminator for deriving said intelligence and said audio tone signal, an audio amplifier including an electron discharge device operative by application of a control potential thereto, a filter network adapted to pass said first range coupling said discriminator to said audio amplifier, a tone operated squelch circuit, an amplifier and a filter network adapted to pass said second range coupled between said discriminator and said squelch circuit, said squelch circuit including a resonant reed device and circuit means for developing said control potential in response to said audio tone signal and for applying the same to said electron discharge device to render said amplifier responsive so that said intelligence is translated thereby.

6. In a selective communication system a receiver responsive to a carrier wav modulated by audio signals in a first frequency range above 300 cycles per second and by a narrow band tone signal in a second range between 100 and 150 cycles per second, said receiver including in combination a discriminator for deriving said audio signals and said tone signal, an audio amplifier including a first electron discharge device subject to cut off by a bias potential, a filter network constructed to pass said first range coupling said discriminator to said audio amplifier, a parallel T-type filter coupled to said first electron discharge device for further rejecting signals in the second range in said audio amplifier, a tone operated squelch circuit including a resonant reed device, a filter network constructed to pass said second range coupled between said discriminator and said resonant reed device, means supplying a negative control potential, said squelch circuit including a second electron discharge device having control and output elements, said resonant reed device having contacts to apply said negative control potential to said control element of said second electron discharge device and cause nonconduction thereof in the presence of said tone signal, circuit means coupling said output element of said second discharge device to said first electron discharge device to apply a cut off bias potential thereto when said second discharge device conducts and to remove said cutoff bias potential and render said audio amplifier responsive when said second electron discharge device is nonconductive.

7. In a selective communication system wherein a plurality of wave signal transmitters are operative on a given carrier wave frequency, and wherein the transmitters transmit carrier waves modulated by tones with each transmitter providing a tone of a different selected frequency, a receiver for operation in such system including means for receiving and demodulating the carrier wave, said receiver having a limiter stage therein providing a source of negative potential, an amplifier for the demodulated intelligence which amplifier is inoperative when a control potential is applied thereto and operative when said control potential is removed, and a squelch control circuit including a control tube adapted to conduct and apply a control potential to said amplifier and to be nonconductive to remove said control potential, said squelch control circuit also including an amplifier having low pass filter means for the demodulated tones, a resonant reed device coupled to said amplifier and constructed to be operated by a demodulated audio tone of one selected frequency, said reed device having contacts to apply said negative potential to said control tube to render the same nonconductive when an audio tone of said selected frequency is present for causing said amplifier in said receiver to be operative.

8. In a selective communication system, a receiver responsive to a carrier wave modulated by intelligence in a first frequency range and by a control signal in a second frequency range lower than said first range, said receiver including in combination, receiver detector means for deriving the intelligence and the control signal, amplifier circuit means including an electron discharge device, a filter network adapted to pass said first range and intercoupled between said receiver detector means and said amplifier circuit means, a tone operated squelch circuit including a resonant reed device responsive to a control signal of particular frequency, and circuit means responsive to operation of said reed device for rendering said amplifier circuit means operative, said squelch circuit further including a limiter stage coupled to said reed device and a band reject filter connected between said limiter stage and said receiver detector means, said band reject filter being constructed to reject signals in the first frequency range to reduce false response of said reed device, and said limiter stage providing a driving control signal of fixed amplitude for said reed device.

9. In a selective communication system, a receiver responsive to a carrier wave phase modulated by intelligence in a first frequency range and by a control signal in a second frequency range lower than said first range, said receiver including in combination, discriminator means for deriving the intelligence and the control signal, audio amplifier means including an electron discharge device, means for applying signals in said first range to

said audio amplifier means, a tone operated squelch circuit including a resonant reed device responsive to a control signal of particular frequency, and circuit means responsive to operation of said reed device for rendering said audio amplifier means operative, said squelch circuit further including a limiter stage coupled to said reed device and a band reject filter connected between said limiter stage and said discriminator means, said band reject filter being constructed to pass signals in the second frequency range and signals above the first frequency range and to reject signals in the first frequency range to reduce false response of said reed device, and said limiter stage providing a driving control signal of fixed amplitude for said reed device.

10. In a selective communication system, a receiver responsive to a carrier wave modulated by intelligence in a first frequency range and by a control signal in a second frequency range lower than said first range, said receiver including in combination, receiver detector means for deriving the intelligence and the control signal, amplifier circuit means including an electron discharge device, a filter network adapted to pass said first range and coupled to said receiver detector means to apply the intelligence signals to said amplifier circuit means, a tone operated squelch circuit including a resonant reed device responsive to a control signal of particular frequency and circuit means including a control valve responsive to operation of said reed device for rendering said amplifier circuit means operative, said squelch circuit further including a limiter stage coupled to said reed device and a band reject filter connected to said receiver detector means, and amplifier means coupled between said band reject filter and said limiter stage, said band reject filter being constructed to reject signals in the first frequency range to reduce false response of said reed device and said limiter stage providing a driving control signal of fixed amplitude for said reed device.

11. In a selective communication system, a receiver responsive to a carrier wave phase modulated by voice intelligence in a first frequency range and by a tone control signal in a second frequency range lower than said first range, said receiver including in combination, discriminator means for deriving the voice intelligence and the control signal, audio amplifier means including an electron discharge device for translating the voice intelligence, means to apply the voice intelligence to said audio amplifier means, a squelch system including a resonant reed device responsive to a control signal of particular frequency and circuit means including a control valve responsive to operation of said reed devicc for rendering said audio amplifier circuit means operative, said squelch system further including a band reject filter connected to said discriminator means, tone amplifier means coupled between said band reject filter and said reed device, said band reject filter being constructed to reject signals in the first frequency range to reduce false response of said reed device and said tone amplifier means providing a driving control signal for said reed device, carrier presence detector means including a rectifier circuit coupled to said discriminator means and to said control valve for controlling the same to render said audio amplifier means operative in the presence of a carrier wave and inoperative in the absence of a carrier wave and in the presence of noise components, and switch means for rendering operative and inoperative said carrier presence detector means thereby providing respectively carrier wave squelch system operation and tone control signal squelch system operation.

12. In a selective communication system, a receiver for a carrier wave which may be phase modulated by voice signals and a control tone in a frequency range lower than the voice signals, said receiver including in combination, receiver circuit means including limiter means and discriminator means for deriving the voice signals and the control tone and noise components received by said receiver, an audio amplifier circuit for the voice signals including a filter connected to said discriminator means for rejecting signals in the frequency range of the control tone, a resonant reed operative in response to a control tone of particular frequency, a tone amplifier circuit for applying signals to said resonant reed and including filter means coupled to said discriminator means for rejecting the voice signals and applying signals in the frequency ranges above and below that of the voice signals to said tone amplifier circuit, said tone amplifier including a limiter stage for driving said resonant reed with signals of a fixed amplitude, a control circuit including an electron valve adapted to be cut off in response to operation of said resonant reed, said control circuit including means connected to said audio amplifier for rendering the same inoperative in response to cutoff of said electron valve, carrier wave squelch circuit means including a rectifier circuit connected to said receiver circuit means and responsive to the presence of a carrier wave for cutting off said electron valve and further responsive to the presence of noise signals in the absence of a carrier wave to maintain said electron valve in conduction, and switch means connected to said carrier wave squelch circuit means for disabling the same so that said audio amplifier is rendered operative only upon reception of a control tone operating said resonant reed.

13. In a selective communication system, a receiver responsive to a carrier wave phase modulated by audio intelligence in a first frequency range and by a narrow band audio tone signal in a second frequency range below said first range, said receiver including in combination, a discriminator for deriving said intelligence and said audio tone signal, an audio amplifier including an electron amplifier device and circuit means to render said electron amplifier device operative to conduct intelligence signals only upon application of a control potential of given value thereto, a filter network adapted to pass said first range and exclude said second range coupling said discriminator to said audio amplifier, a tone operated squelch circuit including an amplifier-limiter circuit for the tone signal and a filter network adapted to pass said second rangc coupled between said discriminator and said amplifier-limiter circuit, said squelch circuit also including a resonant reed device tuned to a tone signal and circuit means for developing said control potential in response to said audio tone signal and for applying the same to said electron amplifier device to render said audio amplifier responsive so that said intelligence is translated thereby.

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Tone Signaling
at
Motorola Incorporated

One of the principal objectives of this case is to make the student (particularly the electrical major) realize that normally more than one discipline is involved in the solution of engineering problems and that, particularly in the larger companies, engineers work as teams.

It is also worth noting that the use of actual patents familiarizes the student with this important facet of the commercial world. The introduction of management practices, i.e. the Project Proposal, Exhibit A-1 and the Progress Planning Chart, Exhibit A-2, should remind the student that engineering, unlike pure research, is a profession where such things as economics and adherence to schedules are important; and that a successful engineer must find a balance between such mundane factors and the more interesting and glamorous scientific aspects.

If the students' backgrounds warrant and time permits, assignment of both electrical and mechanical problems would be appropriate. However, part (A) can be used equally well for electrical or mechanical engineering students whose backgrounds are not adequate for both. For electricals, circuits of greater or lesser complexity, depending upon the level of the students, should be substituted for the circuits shown in Figures 1 and 2. For mechanicals, a suggestion is to assign requirements such as the determination of the natural frequency of vibration of a reed of given stiffness, weight, and dimensions, when firmly clamped at one end. Another requirement might be to determine the natural frequency of vibration of a body of given weight and dimensions when suspended top and bottom by springs of given characteristics.

Appendix A-1, "Frequency modulation communications," explains frequency modulation systems in a manner which should provide all the information needed concerning such systems.

Part (B)

Part (B) includes Motorola's solution, Exhibit B-1, to the problem posed in Part (A). The remainder of this part is completely open ended so that the instructor can adapt it to his particular needs. Depending upon the level and sophistication of the students and the objectives of the instructor, this part may be used for further exercises on the fundamentals of R, L, and C, circuits or for a study or design of electronic circuitry. It may be used equally well for further study of the fundamentals of vibratory bodies, or it may be used to study the effect of shock on the dynamic operation of a multisuspended vibratory body, or to the design of a system to minimize the effect of shock on the dynamic response of a multisuspended vibratory body.

Part (C)

Part (C) is Motorola's solution to the problems posed in Part (B). It is made a separate part so it may conveniently be withheld from the student until he has met the instructor's requirements in Part (B).